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RADIO
FOR THE
AMATEUR

RADIO

FOR THE

AMATEUR

The Underlying Principles of Receiving and the Construction and Operation of Receiving Sets

By

A. H. PACKER

AND

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1922

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PREFACE

The widespread popularization of "wireless" has brought on the market a very large number of books, pamphlets, magazines, etc., designed to satisfy the popular demand for information or for instruction.

Examination of these will show that they can be divided into two classes, i. e., they are intended either to be theoretically instructive, or to give directions covering the erection, or the use, or the construction of radio apparatus.

The present volume is intended to fall in both classes, for it not only gives the theory of operation in a simple manner, but also shows how to construct the more simple parts of radio sets.

Considered in the abstract, this would be an enormous task, and many volumes might be written in performing it. But this is just what the authors have wished to avoid. Very many of the books on the market that purport to tell of the principles of radio transmission do so in a scientific manner, it is true, but are not "popular," in the sense of meeting the need of an uninstructed public for elementary information, and for simple basic principles.

There is a public demand for a book that will do this—for a book that will "begin at the beginning," and will explain the simple natural laws involved, in such a way that the amateur may simply and easily gain a real understand-

ing of what he is doing when he receives, when he uses his tester, when he "tunes" his apparatus, and so on.

This is what the authors have set out to do and it is their sincere hope that by the simple manner used, and by the multitude of drawings and illustrations, the book will satisfy every question of the amateur, and give him an understanding of this wonderful subject more easily and quickly than he could get in any other way.

A. H. Packer

R. R. Haugh

Chicago, June, 1922.

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(In place of the conventional Chapters, the book is divided into "Messages" from the authors to the readers.)

MESSAGE NO. 1

PURPOSE AND SCOPE OF THIS BOOK

This book is a wireless or radio message to you from the authors. *Your two eyes* and the intelligence behind them make up your *receiving set,* while the clearness of the message will depend on how well you *tune up* and the *frequency* with which you *receive* and study these messages.

Do you wish to know why radio works as it does?

These messages will tell you.

Are you content to operate a set without knowing why you turn the little knobs?

These messages will tell you.

When your set gives trouble, do you know how to locate the cause?

These messages will tell you.

Do you wish to build your own equipment, and have it work?

These messages will tell you how.

MESSAGE NO. 2

RADIO WAVES

We Hear with Waves

When your friend in the next room calls your name, you would not know it if the action of his voice did not start little vibrations or waves in the air, which travel rapidly to you. When they reach your ear drums they reproduce vibrations which we interpret as sound.

When the Indian put his ear to the ground to catch the thunder of the stampeding buffalo, it was to hear more distinctly, for the sound waves traveled faster through the earth than through the air.

We See with Waves

The American Indian also used radio of a certain sort, for he signaled with smoke columns which were visible for many miles, and the ability of the absent members of the tribe to get the signal depended on *light waves* which, reflected from the column of smoke and *received* on the eye, gave the mental impression that we call sight.

Limitations of Sound and Light Waves

The use of the voice in sending a message to another is quite limited as to the distance through

which transmission is successful, for a number of reasons. One is that as the sound waves spread in all directions they become weaker and weaker, so that the sound becomes indistinct at a distance. Another limitation is the slow speed with which sound travels, the speed of transmission through air being at the rate of 1,130 feet in a second. The slow speed of sound can be checked by the time it takes an echo to return after calling to someone on the other side of the river. The same condition is noticed when a gun at a distance is fired, the puff of smoke being seen a few seconds before the report is heard. Lightning and thunder illustrate the same point, the flash occurring first, and the thunder or sound of the flash being heard later on account of the time required for the sound waves to travel to the listener from the point where the flash occurred.

In the Signal Corps wig-wag system, the limitation of sound gives way to transmission at greater distances, because with the use of light waves, the only real limitation is the ability of the eye to focus for very great distances; but the speed of light is so great that there is no trouble in this direction, for while sound travels 1,130 *feet* in a second, light will travel 186,000 *miles* in a second. Another limitation of transmitting with light is that an intervening obstruction, like a mountain, puts the system out of commission.

Sound and light both have the limitations due to obstructions. For example, a voice in the next room may be indistinct due to the door being closed, while light waves are interfered with by nearly all substances, glass being the chief exception.

Hearing with Radio Waves

When, with a receiving set, we can listen to a wonderful musical selection being played miles away, it is due to the fact that this method overcomes most of the limitations that are inherent in sound and light waves. The transmission of radio waves overcomes the slow-speed difficulty of sound, for it travels with the same speed as light, or 186,000 miles per second. At the same time it overcomes the difficulty experienced with light waves, for it can travel through closed doors, and other obstructions which absolutely stop the light waves, for it is based on electricity and magnetism, two wonderful servants of humanity, who have never been known to go on a strike, or to quit for an instant their useful labors.

What Makes Radio Work

Just *waves, waves* and *waves,* and still more waves. We know what waves look like when there is a storm on the lake, but you may say, "What is the connection between the waves of water and

the action of a receiving set?" Of course the receiving set does not have exactly the same kind of waves, for it is not even wet, but the action of the waves on the lake is so similar to the action of electricity and magnetism used in radio work, that it gives a good idea to start on.

MESSAGE NO. 3

ELECTRICITY THE FOUNDATION OF RADIO

Would you consider the construction of a house without a foundation? Of course not, but equally foolish would it be to try to understand radio receiving without some idea of electricity and how it is produced.

Now the production of electricity is very simple, and one of the methods of producing it can be compared to the burning of coal which produces heat; for we shall show how the burning of a piece of zinc in sulphuric acid produces electricity.

In Fig. 1 is shown a furnace in which coal is being burned to produce heat, the requirement for successful operation being sufficient draft, or flow of air, to make the coal burn. The air is needed because it contains oxygen which combines chemically with the elements in the coal, and the result of the chemical combination is heat. In similar manner, in Fig. 2 we have a combination that will produce electricity. Here we have a glass containing sulphuric acid and a piece of zinc and a piece of copper, and when these two pieces of metal are connected by a wire, an electrical current flows in the wire as shown by the arrows, while at the same time the zinc is eaten up or destroyed by the acid.

Points of similarity in the two illustrations are as follows:

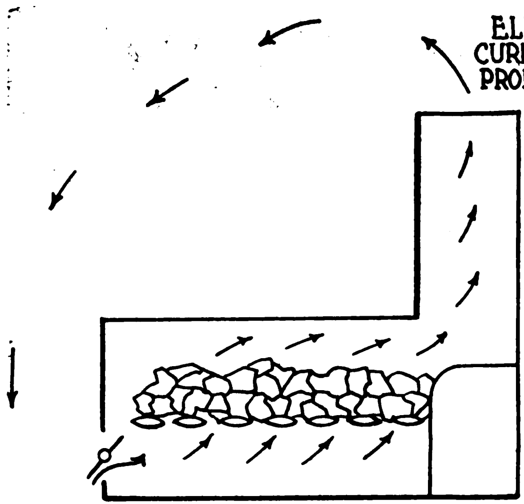

Fig. 1—Burning Coal in Air Produces Heat

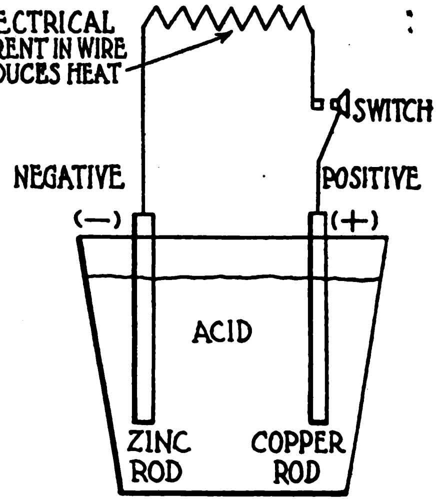

Fig. 2—Burning (Dissolving) Zinc in Acid Produces Electricity

The coal is burned or destroyed by chemical action with the air or oxygen.	The zinc is burned or destroyed by chemical action with the acid.
Destruction of the coal in this chemical combustion produces heat.	Destruction of the zinc in this chemical combustion produces electricity.
Combustion of the coal depends on *circulation* of the air which, when stopped by a damper, tends to stop the combustion.	Combustion of the zinc depends on *the circuit* of wire which, if broken by opening the switch, stops the chemical action.
Flow of heated gasses comes out of chimney and a return of gas or air comes in at opening under the grate.	Current comes out of the electrical cell at the copper strip, and returns at the zinc strip.
The hot air in the chimney, being lighter than the cold air entering under the grate, produces a difference of pressure, which keeps the air circulating.	A natural chemical difference in the copper and the zinc gives a difference of electrical pressure (called voltage), which keeps the electrical current circulating.

The Primary Cell

The illustration we have just given of the action of zinc and copper in sulphuric acid is known as a

primary cell; when the zinc has been all eaten away, the cell is of no further value for the production of electricity, just as in the furnace, no further heat will be produced when the coal is all burned away.

The Storage Battery

The storage battery, which is composed of a number of storage cells usually built up in one case, is somewhat like the primary cell, except that the chemical action in it is reversible. When, for example, the current has been allowed to flow from the positive terminal of a storage battery until the battery is discharged, and the material of the plates is nearly all gone or burned up in the acid, it is then possible by reversing the current, and forcing current to flow in at the positive terminal and out at the negative terminal, to restore the plates to practically their original condition.

In the furnace, it would be like forcing air down the chimney and out the bottom, thereby converting the ashes back into coal again. This, of course, is impossible, and similar action in the primary cell is impossible; but the storage battery *does* have this very valuable property, which enables it to be used over and over again.

Generating Electricity by Friction

Another method of generating electricity is by friction, such electricity being known as static

electricity. This class of electricity is noticed when combing one's hair on a cold day, a crackling sound being heard, and the electrical charges also causing the hair to stand on end. This is also noticed in stroking a cat's back on a cold day, sparks being seen, and the tendency for the hair to stand on end also being evident. Another illustration is the slight shock obtained on a cold day by walking quickly across the carpet and touching a radiator.

Magnetism (Another Foundation Stone in Our Radio Structure)

Just as the waves on the lake depend on both wind and water, so does our radio receiving depend on both electricity and magnetism, and on the relation between them.

We are all familiar in a general way with the action of magnetism. We know that the great ships going across the ocean are guided by the use of a compass, which is a delicately made magnetic needle, carefully pivoted so that it can point toward the north. To do this there must be a *force acting through space* which holds the needle in a certain position. In similar fashion our radio depends on *action through space* which is based on this same principle. This action of the compass needle is due to the magnetism of the earth, the effect of two poles of the earth's magnet being felt *everywhere,* out of doors or in the house, its

useful and guiding force passing through wood, stone, air, and knowing no obstruction able to stop it. So it is with our radio set, unlocking treasures before unknown, the *magic wand* of modern times, and *you* are the magician.

Other characteristics of magnets you are also familiar with: how it will pick up tacks, and pieces of iron or steel, this action being noticed especially at the ends of the magnet. These ends, where the magnetic force or line of action is observed, we call the poles, just as the ends of the earth where the center of magnetic action is felt are called poles.

Magnets of two general shapes are commonly used, one being the horseshoe magnet, and the other the bar magnet. A common application of the horseshoe magnet is found on the regular automobile type of magneto where its relation to electricity is used to produce the sparks that run the engine. The bar magnet is similar, being just like a horseshoe magnet straightened out. In either type the ends are the points that show the power of attraction.

Now if the pole or end of a magnet is brought near a tack, it will be found that the tack will suddenly jump to the magnet. Perhaps it does this when the space between them is one half-inch. If this is the case, it will be found that at greater distances the attraction is not enough to cause the

movement of the tack, showing that the effect of the magnet is less as the distance increases.

This action of magnets which shows attraction through space but which decreases in strength as the distance becomes greater we explain with the theory of "lines of force," which gives us a convenient way of thinking of the action of magnets.

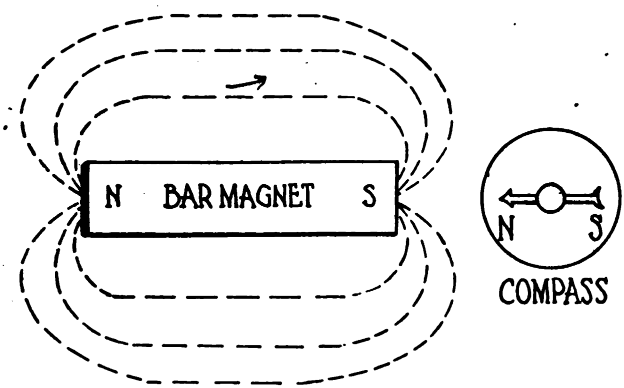

Fig. 3—Bar Magnet Attracts Compass Needle

In Fig. 3 this power that the magnet has to *act through space* is illustrated, for the compass needle that would tend to turn toward the north of the earth is attracted by the south pole of the bar magnet which is marked "S," and is held in this position. Here we note a law of magnetism, that unlike or different poles attract each other; and if the bar magnet had been turned the other way we should find that it would attract the other

end of the compass, so that it would point in exactly the opposite direction.

In Fig. 3 we have represented the bar magnet as having lines of force which proceed from the North (N) pole and travel through space to the South (S) pole, extending in ever-widening circles and becoming weaker or farther apart as they get farther from the magnet. So while only a few of the lines are indicated, there are really some that leave the North pole and after curving out through space come back past the compass and act on its North pole, drawing it toward the "S" end of the bar magnet.

Rules of Magnetic Attraction

We now come to a seeming contradiction, for the North end of the compass needle will point toward the North pole of the earth, but points toward the South end of a bar magnet. This is due to the fact that when magnetism was first discovered, these simple laws about it were not known, and because one end of a magnet would point toward the North, it was called a North pole.

So much of our electrical and magnetic theory has been built up around this supposition, that it would mix everybody up if it were changed, so we explain things by pretending that near the North geographic pole of the earth there is a South magnetic pole, which would account for the

attraction which turns the compass needle toward the North pole of the earth.

Electricity Produces Magnetism

If you should take a piece of copper wire and move it near a compass, it would have absolutely no effect on the action of the needle. However, if you should take the same piece of copper wire

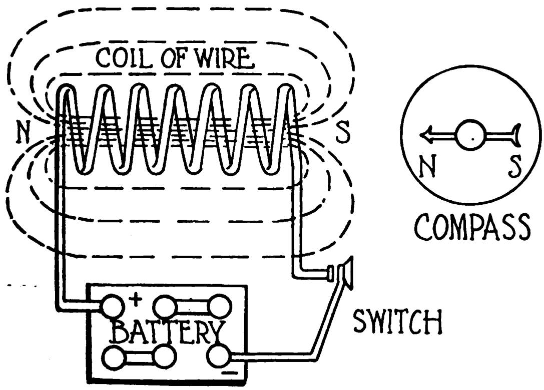

Fig. 4—Coil of Wire Carrying Electric Current Attracts Compass Needle

and roll it up into a coil and run an electric current through it, you would then see that it had a very strong effect on the same compass needle. This action is illustrated in Fig. 4 where a coil of wire is connected to a storage battery in such a way that closing a switch will send current through the coil. This coil of wire *with current flowing* will now act just like the bar magnet, but *with the switch open it will have no effect.*

This magnetism produced by electricity is exactly the same kind produced by the earth or by the bar magnet, and has the same wonderful ability to act *through space* and also through obstacles, such as the wall of a building. Its action is also represented by lines of force as in the case of the bar magnet, for they proceed from one end of the coil and go out through space and return to the other end of the coil, forming continuous loops.

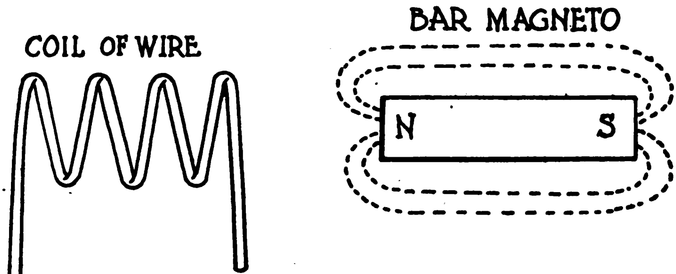

Fig. 5—Bar Magnet Near a Coil Generates no Electrical Voltage

Magnetism Produces Electricity

The ability of electricity to produce magnetism is somewhat like the reversible process in the storage battery, for we can also make magnetism produce electricity, and it is perhaps the most important method we have of developing this form of energy. In Fig. 5 we have a simple bar magnet and near it a coil of wire, and while there is no movement of either we have no electricity pro-

duced. Referring now to Fig. 6 we show the bar magnet being suddenly thrust into the coil. *While it is moving in there is electrical pressure* or voltage induced in the coil, which could be detected with a delicate meter, or if the magnet were moved fast enough it would be possible to get a shock by holding the two ends of the coil which are marked "Plus" and "Minus."

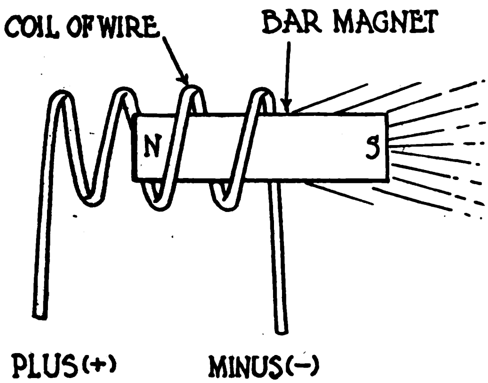

Fig. 6—Bar Magnet Thrust Suddenly into a Coil of Wire Does Generate Electrical Voltage

In Fig. 7 we show the bar magnet at rest in the coil of wire, and again we find that there is no electricity being produced, while in Fig. 8 the magnet is suddenly jerked out of the coil, and electrical voltage is again generated, but in the reverse direction from the voltage shown in Fig. 6.

While the direction of pressure is different in the two cases, the amount or intensity is the same,

if the speed is the same in withdrawing the magnet as in thrusting it in.

From the experiments illustrated in Figs. 5, 6, 7, and 8, we conclude that *changing the magnetism or number of lines of force in a coil generates a voltage in that coil.*

We also find that the faster the magnet is moved either in or out of a coil, the greater will be the voltage produced, and therefore we conclude that *the faster the magnetism in a coil is changed, the greater will be the induced voltage.*

Induced Voltage with Two Coils

In Fig. 4 we saw how electricity could produce magnetism, but in this sketch the magnetic action would be present only if the switch should be closed. With the switch open there would be no circuit and therefore no current and no magnetic lines of force to affect the compass. Then in either closing or opening the switch we have produced a change in the condition of magnetism around the coil.

Changing magnetism, however, in the vicinity of a coil produces electrical pressure or voltage, as shown in Fig. 6 and Fig. 8, so that if we should make and break the current in a coil when it is near another coil, we should produce electricity in the second coil. Such a condition is shown in Fig. 9 where two coils are placed side by side, one being connected to a delicate indicating meter,

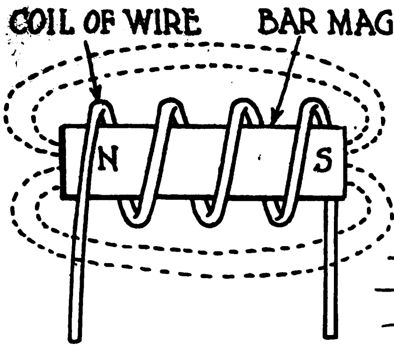

Fig. 7—Bar Magnet Allowed to Stay in a Coil Does Not Generate Electricity

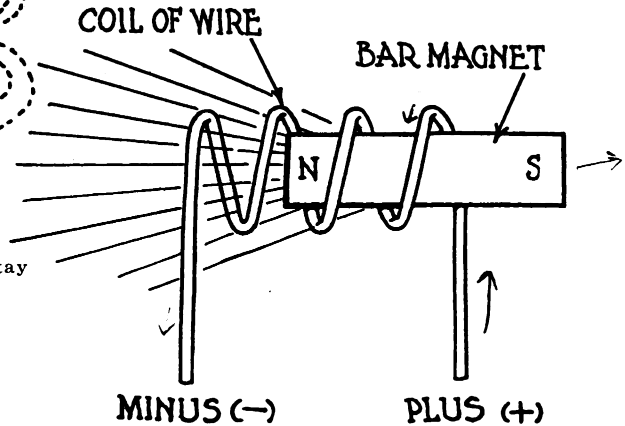

Fig. 8—Bar Magnet Suddenly Jerked Out of a Coil of Wire Generates Electrical Pressure in the Reverse Direction

while the other is connected through a switch to a battery, *but there is no copper connection* between them. With the switch open there is no current, and hence no magnetism, while closing the switch will give the coil at the right, current from the battery and therefore produce magnetic lines of force which, cutting the coil at the left, will generate a voltage. If we assume that the meter has a needle that is normally in the middle of the scale, then closing the switch in the battery circuit will make it kick to one side, while opening the switch will make the needle jump the other way. Keeping the switch either open or closed, however, will produce no change in magnetism, and will give no action on the indicating meter.

While we have illustrated the action as being due to the opening or closing of the switch, it is evident that if the battery current for any reason should get weaker or stronger, the corresponding change in the magnetism would produce corresponding voltages in the coil at the left, and this mutual action of one coil on the other is a vital principle in the operation of radio equipment.

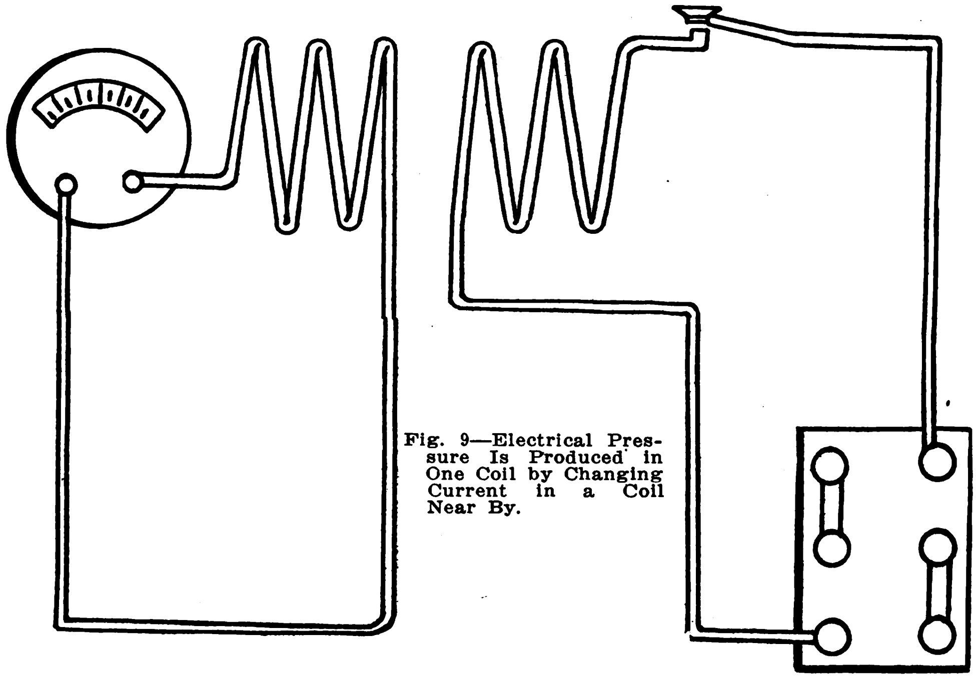

Fig. 9—Electrical Pressure Is Produced in One Coil by Changing Current in a Coil Near By.

MESSAGE NO. 4

CURRENTS

Direct Current

Did you ever watch a piece of machinery that was being driven by a belt, the belt speed being indicated by the slap, slap of the lacing thong as it passed over the pulleys, continually going but never getting anywhere? That is somewhat the way it is with the electricity that we know as "direct current," for while it does not retrace its steps, it keeps going in a definite path or circuit which always comes back to the starting point.

Such a circuit is again illustrated in the case of water being forced to flow through pipes by the action of a pump, and in Fig. 10 such a circuit is shown where the water keeps coming back to the starting point. The pump known as a centrifugal pump has the property, when rotating, of throwing the water from the center toward the outside, so that the water led from the lower pipe into the center of the pump is forced to the outer part of the pump casing by the rotation of the blades, and naturally goes out the outlet shown at the top.

In a similar manner the direct current generator in Fig. 11 sends current out of its positive or (+) terminal into the electrical circuit, and the return is back to the negative or (—) terminal. The generator illustrated is based on the ability

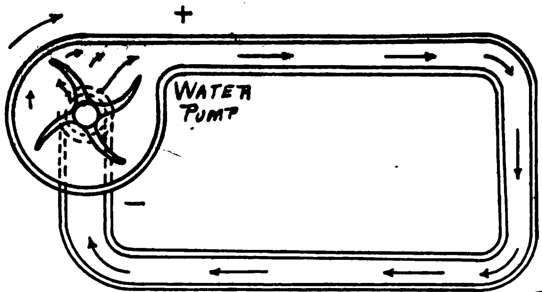

Fig. 10—Water Pump Produces Continuous or Direct Current of Water

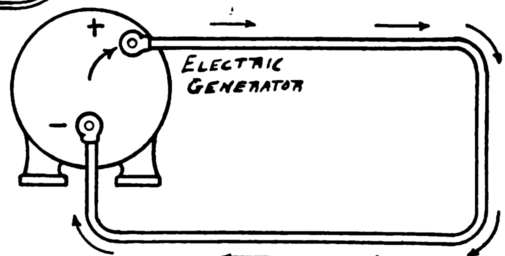

Fig. 11—Electric Generator Produces Continuous or Direct Current of Electricity

of magnetic action to generate electrical voltage, but as we are mostly interested in *radio receiving* we will not bother with the details of generator construction.

The storage battery in Fig. 12 acts exactly like the generator of Fig. 11, for it sends current out the positive and takes it in at the negative terminal, the only difference being that the elec-

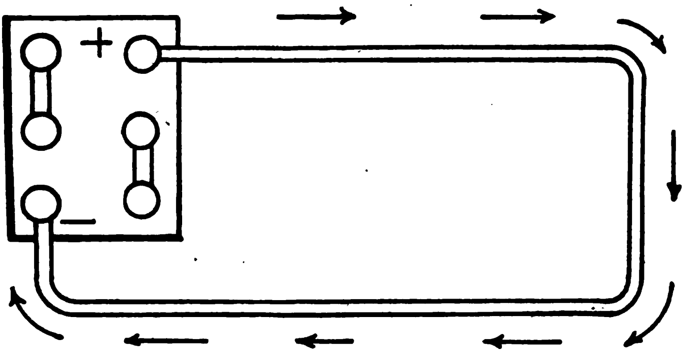

Fig. 12—Storage Battery Produces Continuous or Direct Current of Electricity

tricity is generated chemically instead of by means of magnetism.

In all of these illustrations of direct current we see that there must be a return path, and that the flow is always in the same direction.

Alternating Current

While direct current always flows in one direction, alternating current is quite different, for it

is continuously changing its direction, and flowing back and forth. For example, the balance wheel of a watch is moving back and forth, and while it never gets anywhere it has a useful job to perform. So it is with alternating current which has useful things to do in spite of the fact that it never gets anywhere.

Let us again consider a belt connecting two pulleys, but let us assume that the driving pulley, instead of rotating in a certain direction, is oscillating back and forth like the balance wheel. Then the belt would also be moving back and forth, and would transmit to the other pulley the same oscillating motion.

The production of alternating current might be illustrated by the mechanism in Fig. 13, where back-and-forth motion of a piston produces an *alternating current* of water in the passage ways.

At the right in the figure we have a cast-iron cylinder in which a piston moves, while the opposite ends of the cylinder are connected by a passage way, up above the main part of the cylinder. The piston has an extension which is connected by a connecting rod to a rotating crank, which is turning at uniform speed.

As the crank continues to turn, as shown by the arrow, the piston will move over to the right and force the water ahead of it, producing the current indicated by the arrows.

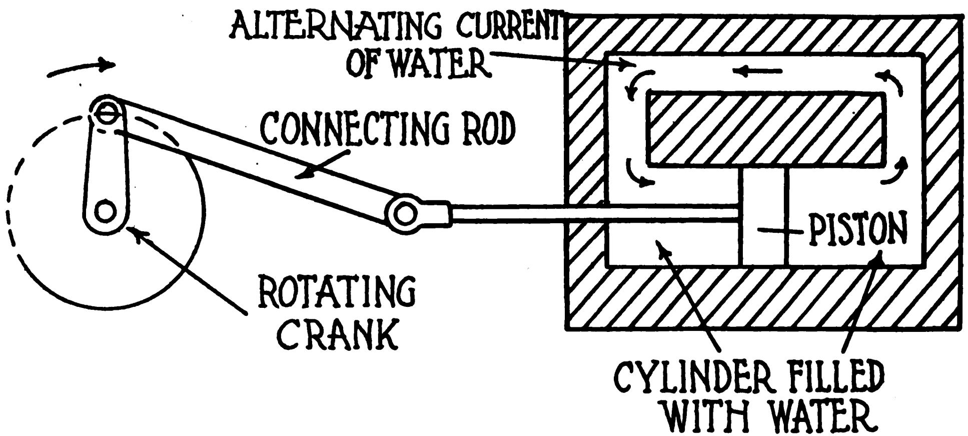

Fig. 13—Back-and-Forth Motion of Piston Produces Alternating Current of Water

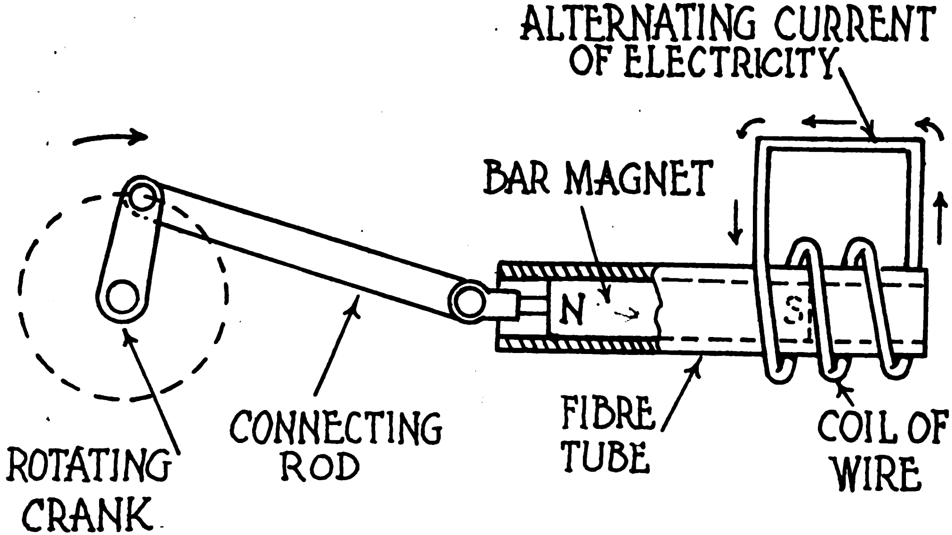

Fig. 14—Back-and-Forth Motion of Magnet Produces Alternating Current of Electricity

As the crank gets to its extreme right-hand position, however, no further motion of the piston will take place, until continued rotation of the crank starts to pull the piston back again. This will now force the water in just the opposite direction to that shown by the arrows, so that continuous rotation of the crank will produce *alternating* action of the piston and therefore an *alternating current* of water in the passage ways.

Similar to the water circuits of Fig. 13 are the electrical circuits of Fig. 14, a crank and connecting rod moving a bar magnet in and out of a coil of wire, just as the piston was moved back and forth in the cylinder. In the position shown, the bar magnet is being pushed into the coil of wire which is wound on one end of a fiber tube. This principle was shown in Fig. 6, where the magnet moving into the coil generated a voltage. As the crank gets to the right it will for an instant produce no motion of the magnet and will at this instant generate no voltage as previously illustrated in Fig. 7, in spite of the fact that the magnet is in the coil. As continued motion of the crank starts to pull the magnet out, however, a voltage will again be generated, but in the opposite direction, as previously illustrated in Fig. 8.

The back-and-forth motion of the magnet will then produce an *alternating voltage* in the coil which will send an *alternating current* through the connection or by-pass from one end of the coil

to the other. The arrows along the wire show the direction of current only for the position of the crank where it is pushing the magnet in, but the current will be in the other direction as soon as the magnet is moved out again.

What Is Frequency?

Frequency is a term used in connection with an event that is continually being repeated, and denotes the rapidity with which it is repeated.

In Fig. 14, for example, the frequency with which the magnet moves in and out of the coil depends on how fast the crank goes around, and for every turn of the crank the magnet will make one complete trip into the coil and out again. In going in and out it would also induce or produce current in the wire, first one way and then the other.

What Is a Cycle?

When the crank in Fig. 14 has made a complete turn, it has moved the magnet in and out again and is ready to move it in again. This action has also caused current to flow first one way and then the other way in the electrical circuit, and it is ready to start over again in the original direction. This is *one cycle.*

We might say therefore that *a cycle is a series of events, continually being repeated.*

Now suppose that the crank should be turned fast enough to make sixty complete revolutions in a second. This would move the magnet in and out sixty times in a second, and would have induced sixty cycles in the current, for there would have been sixty times each second when current was flowing one way around the circuit and the same number when it was flowing the other way around. If asked the *frequency* of the current in the coil we should then answer, "sixty cycles."

Now sixty cycles is a common frequency with ordinary alternating current, but in *radio work* frequencies are used from 10,000 to 5,000,000, but of course are not produced by any such mechanical means as shown in the sketch.

What Has Frequency to Do with Hearing a Radio Message?

When we hear the first singing of a robin in the early spring, the variation in frequency of the sound waves produced in its throat causes the thing we know as the robin's song. Variation in frequency is the thing that makes the difference between middle C on the piano and the lowest bass note, for the tone we hear is determined by the frequency of the sound vibrations, and the higher the number of vibrations per second, the higher the pitch of the note. So it is that we see that frequency is another of the essential foundation stones of our radio work.

Audio Frequency

When sound waves come to your ear they produce certain vibrations which depend for their rapidity on the frequency of the sound wave, and as the eardrum vibrates in accordance with this frequency we say we hear a certain sound. As the number of vibrations per second is reduced, that is, the frequency is lowered, a point is reached where the eardrum does not respond and we say the rate of vibration is too low to be heard. In similar manner when the vibrations are at too high a rate the ear cannot keep up with them, and again we hear no sound. The range of frequencies that the average human ear can detect is between 32 and 10,000, any frequency in this range being known as "*audio frequency.*" *Radio frequency* is above audio frequency, being from 10,000 up, as previously stated, and current at these frequencies is usually called *high-frequency current* instead of alternating current, although it is the same general kind of current but with many more rapid changes or reversals.

Why Are There Waves in Alternating and High-Frequency Current?

In Fig. 14 we saw that the rotation of the crank and the reciprocating or back-and-forth motion of the magnet would produce alternating current in the coil and its connections, but it may not have

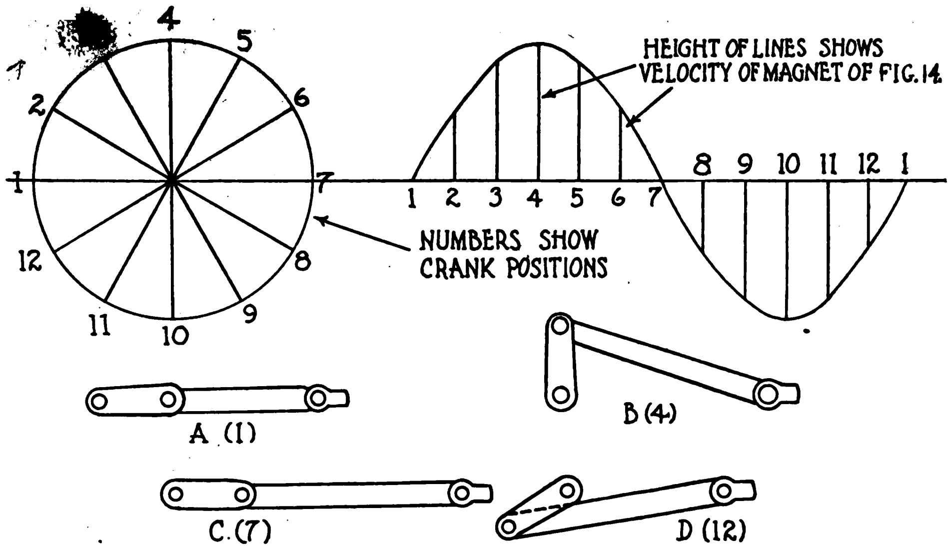

Fig. 15—How Alternating Motion Produces a Wave

been perfectly clear that the variations in current are in the nature of waves.

In the lower part of Fig. 15 are again shown the crank and the connecting rod of Fig. 14, but without all of the detail of the magnet and coil. The four sketches marked (*A*), (*B*), (*C*), and (*D*), indicate different positions of the crank. In the upper left-hand part of this same sketch is shown a circle with twelve different places marked on it which represent twelve crank positions, the lower views showing four of these.

In the first of these positions called (No. 1) we have the crank at the extreme left, so that the magnet would also be at the left, the lower sketch (*A*) or (No. 1) showing this condition. Here, just for an instant, although the crank might be moving, the end of the connecting rod that operates the magnet is *not* moving. Different from this condition is the action at (*B*) or (No. 4) position, where the same angular rotation of the crank will now be producing practically the greatest movement of the magnet. The position indicated by (No. 7) would be just opposite to (No. 1), but would be the same as far as the magnet is concerned, as there is for an instant no movement. At (*D*) is shown position (12) of the crank where it is not quite around to (No. 1) or the starting point, and while the crank is still turning at the same speed, the end of the connecting rod is

moving slowly because of the angular position of the crank.

It is accordingly evident that not only will the motion produced by the crank reverse periodically, but that it varies continuously with the different crank positions, and it is for the purpose of getting an idea of the nature of these variations that the chart or curve has been drawn as the upper right sketch of Fig. 15.

Here a number of equal spaces are laid off, the divisions being marked the same as the crank positions around the circle, there being twelve in each case. Now in order to get a mental picture of the action that takes place, we will draw vertical lines representing the velocity of the magnet's movement for different crank positions. For example, at the (No. 1) and (No. 7) positions, where the crank and connecting rod are in line with each other, there is no movement of the magnet, so the height of the vertical line is zero. On the other hand at position (No. 4), where the crank is as shown at (*B*), the motion is the greatest, so that this line is made the longest. In similar manner the length of the other lines is determined, and a smooth curve is drawn through the points indicated by the tips of the lines, this curve representing the velocity of the magnet for any crank position.

Where the curve is above the line it represents that the magnet is moving into the coil, while dis-

tances below the line represent the speed at which it is being withdrawn.

Now from this curve or chart which expresses at any crank position the corresponding magnet speed, we have what obviously looks like a wave, but as the electrical voltage generated is due to the speed with which we move the magnet, it can also be used for a voltage wave, so that the height of the curve can be used to represent the voltage being produced at any particular crank position. We therefore call it the "A. C." wave, or *alternating-current wave.*

Cycle

In the upper right sketch in Fig. 15 the whole wave, including the high part and the low part, from one to thirteen, makes *one cycle,* so that in 60-cycle current we have sixty of these complete waves per second.

Alternation

Half of a cycle is called an alternation, and includes *either* the upper part *or* the lower part, so that if we have 60 cycles per second we should have 120 alternations per second.

MESSAGE NO. 5

KINDS OF RADIO WAVES

Two Kinds of Radio Waves Carry Messages to Us

The action of radio depends on two types of radio waves, one being known as "damped wave," because after being started it soon dies out, while the other is known as "C. W.," meaning continuous wave, because the action is sustained instead of being allowed to die out.

Damped Water Waves

The use of damped radio waves is similar to the action of the waves produced in a pond or lake when a stone is dropped in the water, the first effect being shown at the top sketch in Fig. 16. The falling stone hits the water and makes a depression or "dent" in the lake. As the water is not capable of compressing, it is forced up on all sides around the stone, and this raised portion of water then flows off in all directions in what we call a wave. A sort of pendulum action of the water now starts, and the water swings up and down in any one place in addition to the spread of the wave formation across the surface of the water. In the second sketch from the top of Fig. 16 we have shown where the first wave or crest has spread out and two other waves have

formed, while in the third sketch there are six waves, and in the fourth sketch there are eight. As the first wave or crest rolls away, the waves at the start keep getting lower and lower, owing to the friction of the different particles of water on each other, and this friction constitutes the

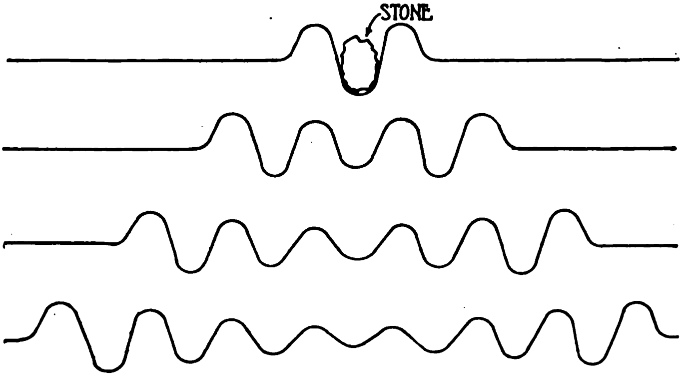

Fig. 16—Damped Water Waves Produced by Dropping a Stone

damping action which will eventually make the surface of the water calm again. Its first effect, however, is to give a series of waves which decrease in height as shown in Fig. 16. These waves spread in all directions, as shown in Fig. 17, the last wave dying out to the level of the surface of the water.

Wave Train

Let us assume, when a stone is dropped, that twelve or fifteen waves are produced which roll

out in all directions. If these would come to a cork floating in the water, they would cause it to jump violently up and down at first and then less

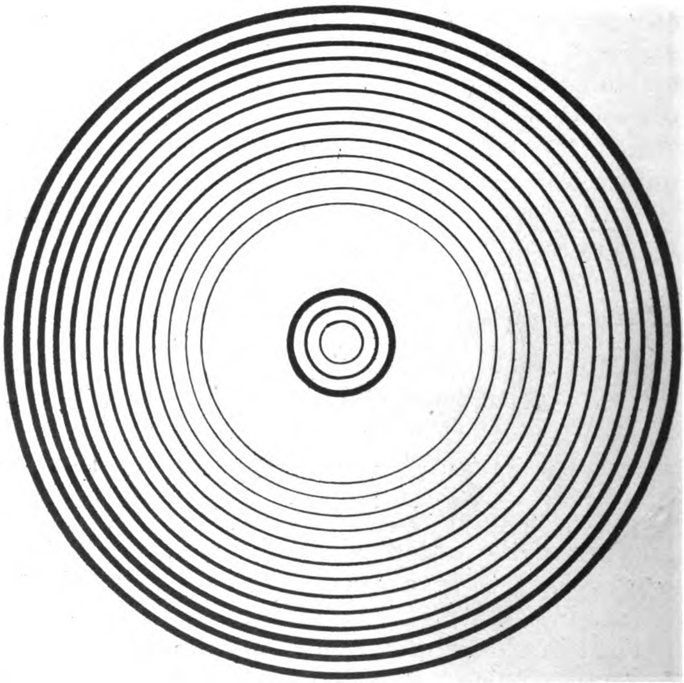

Fig. 17—Series of Stones Dropped in Water Send Out a Series of Wave Trains

violently as the smaller waves reached it, finally quieting down as the last of the wave train passed by. In similar manner does the damped radio

wave strike the receiving apparatus and produce a certain effect upon it.

Now assume that we continue to drop stones in the lake, and that as fast as one wave train leaves, and the surface gets calm, we drop another stone and start another train. Then the action will be as shown in Fig. 17, where one train has left and the dropping of another stone has started another train. Thus a series of messages would be sent out to our floating cork, and by the rapidity of the wave transmission a code might be worked up that could be read by the bobbing cork.

Wave Length

In the illustration of the waves made in water, the wave length is the distance from the top or crest of one wave to the top or crest of the next one. With small ripples this might be three or four inches, while with a storm on the lake it might be five or six feet or more.

Speed of Waves

The speed with which the waves form or travel from the source of disturbance would affect the efficiency of a system. In the case of water, it is exceedingly slow, being about one half-foot per second, whereas sound travels 1,130 feet a second and radio waves travel 300,000,000 meters a second, or 186,000 miles in a second. (A meter is a

little over three feet, being 39.37 inches.) Now let us refer to Fig. 17 and assume that in the outer circle of waves, that is, the first wave train, there are 15 waves or ripples and that they measure 4 inches from crest to crest. The wave length, then, is 4 inches. The length of the train is then 15 times 4 inches, or 60 inches, or 5 feet, and as the wave spreads at the rate of one-half foot per second, it must have taken 10 seconds for the wave train to form, or ten seconds from the time the stone was dropped until the last and smallest wave rolled away and the place where the stone had been dropped was calm again.

MESSAGE NO. 6

THE PURE SOUND WAVE

Did you ever listen to an amateur musician with a new cornet, making night hideous, or to a child just able to reach the keyboard of a piano, and enthusiastically hitting as many notes at once as his fingers could reach? The result is far from pleasing, for the air is full of sounds of assorted wave lengths which are not "in sympathy" with each other, and the human ear registers a mental protest.

The Pure Sound Wave

In Fig. 18 is shown a string or wire such as used in a piano, and at the side is shown a felt hammer with which the wire may be struck in order to make it vibrate. We will assume that this wire is capable of vibrating at the rate of 256 times a second and does so when struck with the hammer. This rate of vibration will produce a tone or sound wave which we call middle C, and whenever anything vibrates at this rate it produces this tone.

Now if the hammer strikes the string but once, we know that the string will vibrate at first, but will soon come to rest as the amplitude or distance sideways decreases. This is due to the tension in the wire, the friction of the air, and the

friction in the material of the wire, all of which tend to "damp" or stop the movement. For this reason there will be sent out through the air a train of waves just as in the case of the water illustration, and this time the ear tells us that the

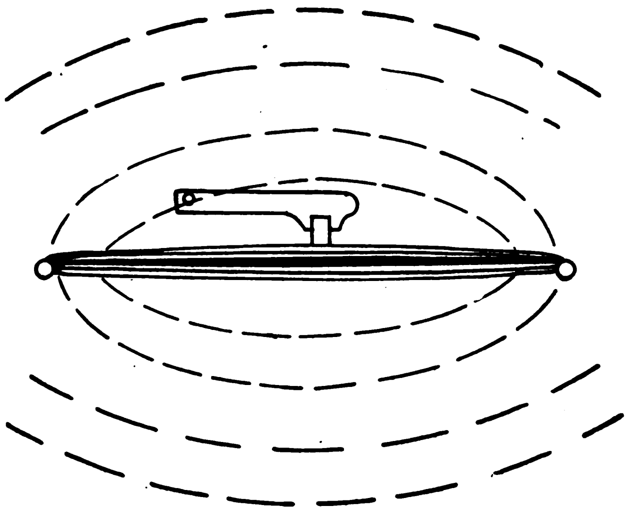

Fig. 18—Felt Hammer Striking a Piano String Sends Out a Pure Sound Wave

waves are getting smaller, for the tone becomes less and less distinct, until we finally can hear it no longer. The *wave length,* however, does not change, for while the tone is dying out and becoming fainter, it continues as the *same note, or tone.*

We shall soon find out the reason for the discord produced by the small child playing the

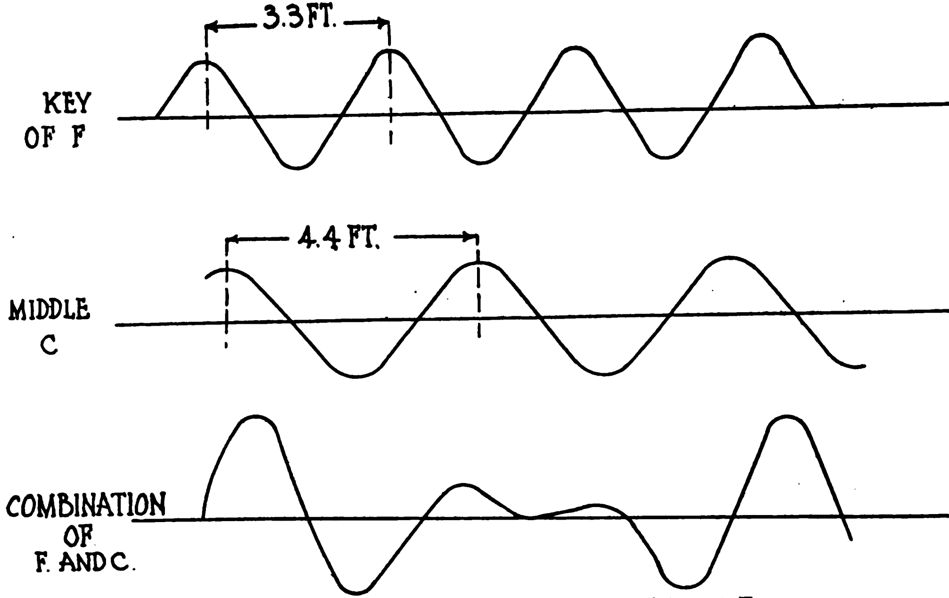

Fig. 19—Combination of Two Sound Waves of Different Frequency Produces a Distorted Wave

piano, for if we consider the key of F above middle C, we find that it vibrates 341 times per second, so that its waves do not have much in common with those produced by the key of C.

The speed with which sound travels is 1,130 feet per second, in which time the key of middle C has produced 256 waves, so that the length of each wave must be 1,130 divided by 256, or about 4.4 feet. In similar manner the wave length for the key of F would be 1,130 divided by 341, or about 3.3 feet.

Referring now to Fig. 19, we have shown at the top the waves that would be made by F, and on the second line the waves produced by middle C. It will be seen that while at the start (shown over at the left) they might have their high spots or crests at the same time, they do not continue to do so, because one is quicker than the other. The result is that the sound wave that strikes the ear is a more or less jumbled combination of the two, and is shown down below, being a very irregular and erratic sort of wave. It is produced in this sketch by adding the vertical height of the separate C and F waves at any point, and using that height for the combination wave.

Now we have considered but two notes of different wave length or frequency, so it is easy to see the reason for the inharmony produced when many miscellaneous notes are struck at once.

Radio tuning, in order to pick up the particular message or music you want, is the process of weeding out all the frequencies you do not want, and getting in tune or "in sympathy" with the sending station you wish to hear. It is fortunate that we can do this, or our *radio receiving set* would be as confusing as trying to listen to a dozen people all talking at once.

It sometimes happens that in playing the piano, when a certain note is struck, some metal object in the room, like the metal rim of a lamp shade, will start to buzz and will do so every time that same note is sounded. In this case the piece of metal happens to be in tune with that particular note, or, in other words, its natural period of vibration is the same as the note, so that the sound waves hitting it start it moving. This corresponds to the *receiving set* tuned to a certain wave length and ignoring all others.

Radio Waves

Just as the water waves start from the source of a disturbance and spread out over the surface of the lake, similar to the way in which sound waves start from the sending point and spread through space, so do *radio waves* start from the sending station and, traveling with the speed of light, come to our receiving station, bringing their message with them.

These waves depend on electricity and magnetism, however, which not only can travel through space, but also through all sorts of substances, so that the receiving device or aerial in the attic, or the bedspring used for that purpose, may work practically as well as the wires strung on the house top.

MESSAGE NO. 7

MAGNETIC EFFECT OF STRAIGHT WIRE CARRYING ELECTRICAL CURRENT

We have already shown the magnetic action of a coil of wire in which electricity is flowing, this action being illustrated in Fig. 4. We now have another way to produce magnetic action, for it is found that even a straight wire can produce magnetic lines of force, which are in the form of circles, this action being illustrated in Fig. 20. At the left is shown a battery with its plus terminal upward, the current flowing up and over to the right and down in the long straight wire, where it produces magnetism in circles around the wire in one direction. In the sketch at the right, in the same figure, the battery is shown reversed, so that the current is also reversed, and we now find that the magnetism is still going around the wire in circles, but goes *the other way around.*

Now while these magnetic circles are shown as a few rings around the wire, they really consist of a force or power manifested around the wire but extending also *out into space* for a very great distance, the local strength of these circles of magnetic action becoming gradually weaker, however, as the distance from the wire becomes greater. Now as these magnetic disturbances are

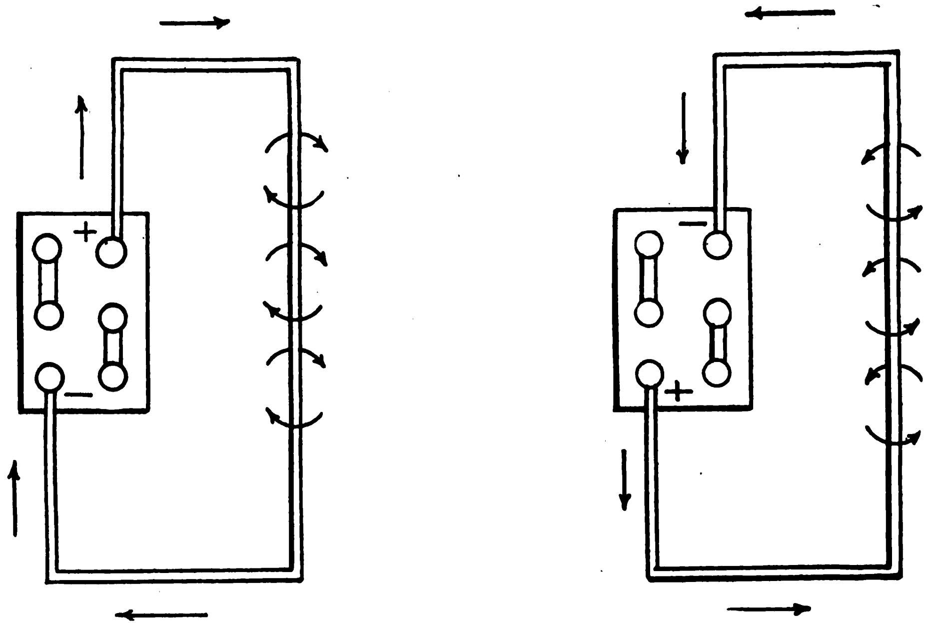

Fig. 20—Electricity Flowing in a Straight Wire Produces Circular Lines of Force Extending Out into Space

produced by the current of electricity and spread as waves through space at the rate of 300,000,000 meters per second, it is evident that it is not long after the connection on the battery has been made that the magnetic action would be in operation at a considerable distance.

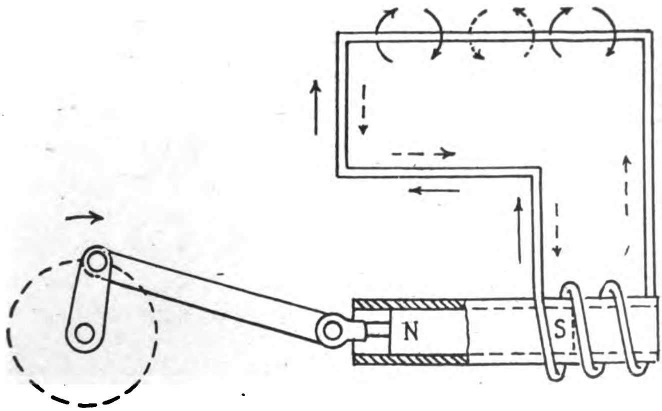

Fig. 21—Alternating Current in a Straight Wire Sends Out Alternating Magnetism in Waves

Alternating Magnetic Waves

Just as the direct current from the storage battery produces a steady condition of magnetism that does not change as long as the current is constant, so does an alternating current produce a magnetic condition that *does* change with every variation of the current. In Fig. 21 we have again shown the general scheme previously illustrated in Fig. 14, but this time it is shown to illustrate the magnetic action of alternating current.

From our previous illustration and discussion we know that revolving the crank will move the magnet up and down in the fiber tube which will produce current in the coil, first one way and then the other, and from the illustration in Fig. 20 we know that current one way in the wire makes the magnetism go around in one direction, and that reversing the current also reverses the magnetism. In the long wire in Fig. 21 we shall therefore have alternating magnetism, springing up with the current and spreading out into space, getting stronger and stronger with the rise in the current, then shrinking again as the current slows down, then spreading out into space again, but with the circles going *the other way around* as the current rises in strength in *the reverse direction.*

We shall then have waves of magnetism going out into space, the *time* from the top or crest of one wave to the next being the same as the time required for the crank to turn once. Now if the crank is turned slowly, the waves will be few and the distance between them will be very great, while if the crank is turned very rapidly, more waves will be produced per second and the distance between them, or the *wave length,* will be less.

Now as these waves travel 300,000,000 meters in a second, the first wave produced will be that far away in one second, and if the crank should

turn 300 revolutions per second, we should have 300 waves spread out over a distance of 300,000,000 meters, so that the length of each wave, or the *wave length,* would be 1,000,000 meters, which of course is much longer than is ordinarily used.

300-Meter Wave

Now suppose that it would be possible to turn the crank 1,000,000 times in a second: Then we should have that many waves spread over a distance of 300,000,000 meters, so that the length of each wave would have to be 300 meters. The *wave length* would then be 300, and the *frequency* 1,000,000.

360-Meter Wave Length

A wave length commonly used is the 360-meter wave, and if we had a distance of 300,000,000 meters filled with these waves, we should have to divide 300,000,000 by 360 to find the number of waves. This comes out 833,333, which would be the *frequency,* while the *wave length* would be 360.

Damped Waves in Spark Sending Sets

For wireless telegraphy, sending is accomplished with a high-voltage spark, the vibrator being capable of producing from 150 to 200 sparks per second. Each of these sparks produces a

radio wave train having from 15 to 25 waves, which have a frequency of about 1,000,000. We might then imagine a space of 300,000,000 meters having in it 150 or 200 short wave trains, equally spaced, the length of each little wave train being very short compared with the space between them.

The wireless signals would then consist of dashes and dots, the dashes containing a large number of noises made on the receiving apparatus by a large number of these wave trains, while the dots would consist of a smaller number of these wave trains which would produce the buzz for a shorter time.

Wireless Telephone Cannot Use Damped Wave

The wave trains which quickly die out are available for use in sending signals only, and correspond to the action of the waves in water which quickly subside after the stone is dropped, or may be compared to the sound from the piano string which also quickly dies out.

Continuous Wave

Suppose that, instead of striking the key of a piano, we should operate an organ key, and continue to hold it. This would produce a note that would continue to sound at the same volume of

tone, for the electric motor continues to operate the bellows, and the key continues to allow air to flow to the organ pipe, so that the waves continue to be produced and do not die out or decrease in height or amplitude as long as we continue to *supply power* to keep them going.

In our *radio work* the same condition can be obtained by continuing to supply power to keep the radio waves from dying out, and this continuous wave, or C. W., is the basis of wireless telephony. While produced by methods that will be considered later, it is somewhat like the results we should have if running the crank in Fig. 21 at the rate of a million or so times per second, *and continuing to run it at that rate* as long as we wished to send messages.

MESSAGE NO. 8

A SIMPLE RECEIVING CIRCUIT, USING AN AERIAL, A GROUND, A CRYSTAL DETECTOR, AND A PAIR OF PHONES

We are going to get right down to business in this message and present the scheme of a simple receiving circuit. We hope you have carefully

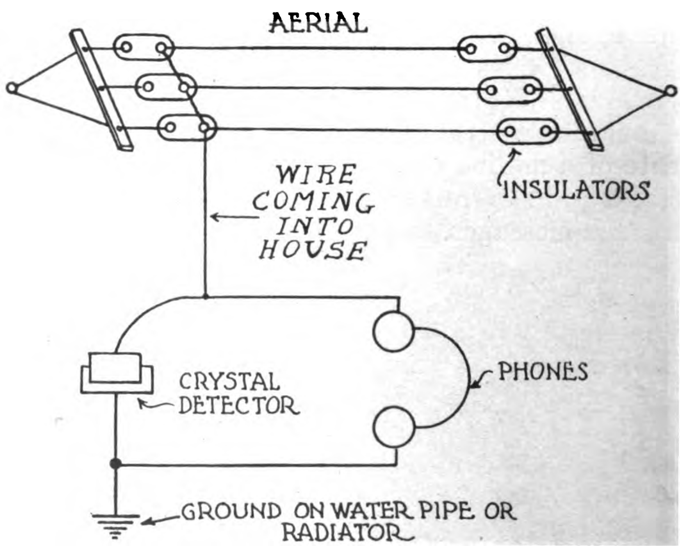

Fig. 22—A Simple Receiving Circuit

read the previous messages, for they are intended to give you an understanding of the underlying principles, so that the discussion of the receiving circuits will appear perfectly simple.

The simple circuit to be taken up now is shown in Fig. 22, and in it will be seen four main parts, these being the aerial, the ground connection, the crystal detector, and the phones or receivers, by means of which we hear the message. The aerial picks the messages out of the air. To understand its action we will refer to Fig. 23 in which is shown a circuit having nothing in it but a sensitive meter and a circuit of wire. Note that there is no battery or similar source of electricity in the circuit. We also have at the right a horse-shoe magnet, and we will assume that it is held in the hand and first moved toward the left so that the poles go one on each side of the wire. Now we know that such a magnet always has lines of force going from its North pole to its South pole, so that when it is moved to the left, as indicated by the solid black arrow at the top of the magnet, there will be a change of magnetic condition around the wire, or the wire will have been cut by lines of force. This will generate a voltage in the wire and will send a small current through the indicating meter as shown by the solid arrows along the wire. Now if the magnet is pulled the other way, or to the right again, the reverse electrical action will take place, and current will be generated in the direction of the dotted arrows. This condition would be shown by the needle on the meter going first one way and then the other way as the magnet is moved back

and forth, and the more rapidly the magnet is moved, the more violent will be the deflections of the needle showing the increase in voltage generated with the increased speed of cutting the lines of force.

What a Ground Is

Electricity is usually carried through copper wires. It is, however, true that the earth will also carry electrical currents, so that it is possible to send electrical current from one place to another through a wire and to use the earth in place of a return wire. In our radio work the earth is used somewhat as a return connection, and the sign that means a connection to the earth is made with a series of lines, each one shorter than the one before it. Such a sign is used in Fig. 22 and labeled "Ground on Water Pipe or Radiator." To make a good connection with the earth we need some piece of metal driven down at least five or six feet, and if the earth is moist it makes a better connection than if dry. However, as in practically every house, we have piping of some kind which comes to our house after being buried in the earth, we have a very easy way of getting a good connection to the earth, without the trouble of driving any bar or pipe down into it.

A "ground connection" is therefore one made to the earth or to a pipe or other metal object which is already connected to the earth. In Fig.

22 it will be seen that one wire from the phones or receivers and one connection from the detector will be connected to the water pipe or "ground."

The aerial action in Fig. 22 is similar to the action of the wire in Fig. 23, for the radio waves

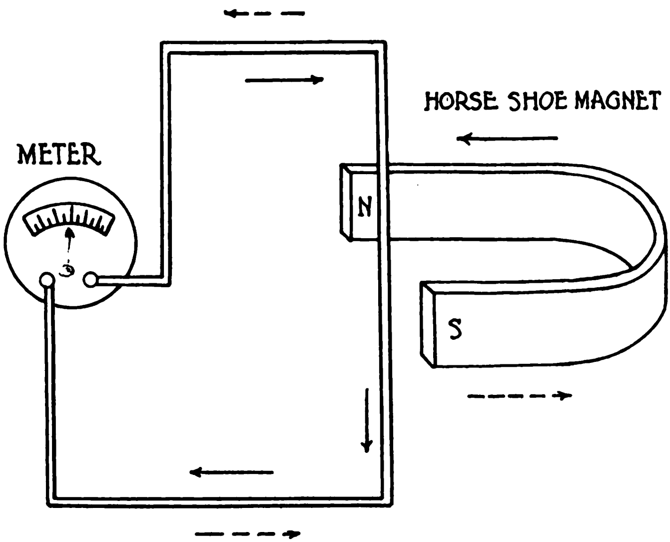

Fig. 23—Magnetism Cutting a Wire Generates Electrical Voltage

or magnetic impulses, advancing and receding through space, generate voltages in the wires of the aerial, or antenna as it is also called, sending little impulses of current down to the earth or ground through the crystal detector or the phones. Now if it were not for the detector, the

advancing and receding radio waves, generating alternating current in the aerial to ground circuit, would also produce alternating current in the phones. This would produce a sound in the phones except for the fact that the alternations are too fast for the phones to follow, so that no sound would be heard. If we refer to Fig. 23 again, it will be easier to understand that the result would be similar to moving the magnet in and out, perhaps a million times a second, which would reverse the current so rapidly that the needle of the meter would not be able to follow each change and would accordingly stand still on zero.

In the aerial circuit to ground, it is therefore necessary to have some sort of device that will allow the current to flow but one way through the phones. The crystal detector is one method of doing this, for it has the peculiar property of letting current flow one way through it, but stops it as it attempts to flow the other way. For this reason it will take an alternating current and carry it easily in one direction, so that the phones do not get any, but when the current reverses the detector will not carry it and the phones then have to carry the current in the reverse direction. Referring again to Fig. 23, we might get the same sort of results if we could disconnect the meter every time the magnet was moved to the right and connect it quickly again when moving it to the left.

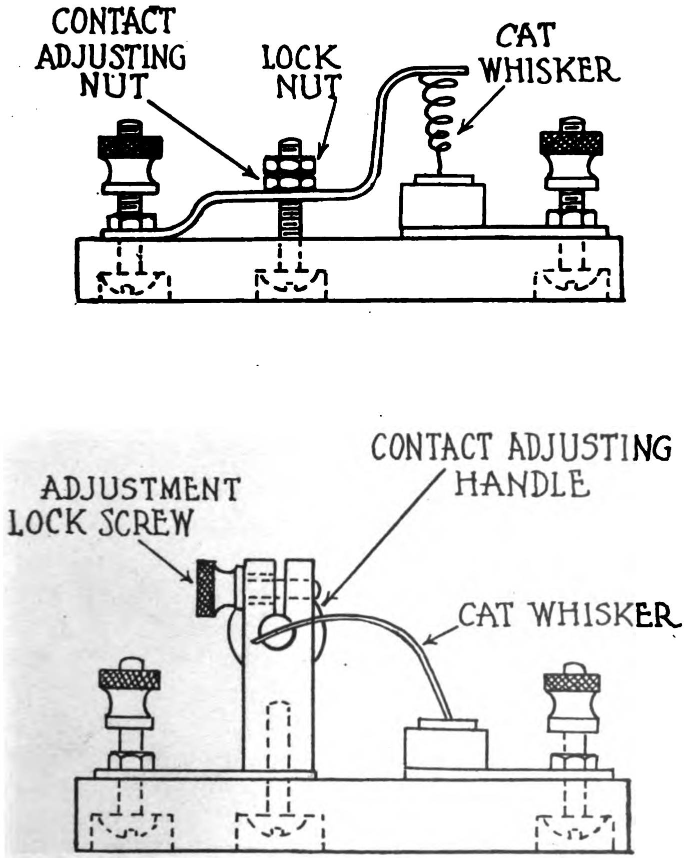

Fig. 24—Two Methods of Constructing a Crystal Detector

In this way we should get impulses in only one direction at the meter, and no matter how fast these came, being in the same direction they would all have the effect of holding the needle in the same direction, and the tendency for it to stay on zero would be overcome.

The Detector and How to Make It

The form of crystal detector most commonly used is made of a piece of galena, which is a common form of lead ore. On the surface of this crystal a fine wire of copper or gold is allowed to bear with slight tension. This contact is the key to the situation and acts something like a turnstile, which is arranged to operate in one direction, and cannot be turned backward. Its action might also be illustrated by the action of the Schrader valve in the inner tube of an automobile tire, which lets the air go in but will not let it come out.

The operation of a receiving set of this type depends somewhat on the exact point at which the fine wire bears on the crystal and also on the tension which it exerts, so that a detector should be made with provision for adjusting both of these conditions.

Making the Detector

In Fig. 24 are shown two simple ways of making a detector. In either one the galena crystal is

set in a cup of metal and is either held in with a clamp or set screw, or else is set in melted solder, which, as it cools, holds the crystal firmly in place. From the crystal holder a strip of brass or copper goes to the binding post at the right.

The binding post at the left in the upper sketch has a piece of spring brass fastened under it, and this extends up and over the crystal, and holds the small wire or "cat whisker," as it is called, in such a way that it bears on the crystal. The "cat whisker" is shown spiraled, so as to make a delicate contact, and the adjusting nut can be turned down if it is desired to increase the tension.

The construction shown in the lower sketch is somewhat better, the "cat whisker" being held in a rod of a quarter-inch radius, clamped in a vertical brass post, which is connected by a brass strip to the binding post at the left. To change the contact adjustment on this type it is necessary only to loosen the lock screw, and turn the round handle, shown at the far end of the quarter-inch rod, and then to tighten the lock screw again. It is also easy with this type of detector to spring the "cat whisker" in or out or sideways to try different spots in the crystal, as some are more sensitive than others.

Note that the end of the "cat whisker" that bears on the crystal should be pointed.

Principle of Telephone Receiver

To have a good idea of how radio messages are received, it is well to understand the general principle on which the ordinary telephone receiver

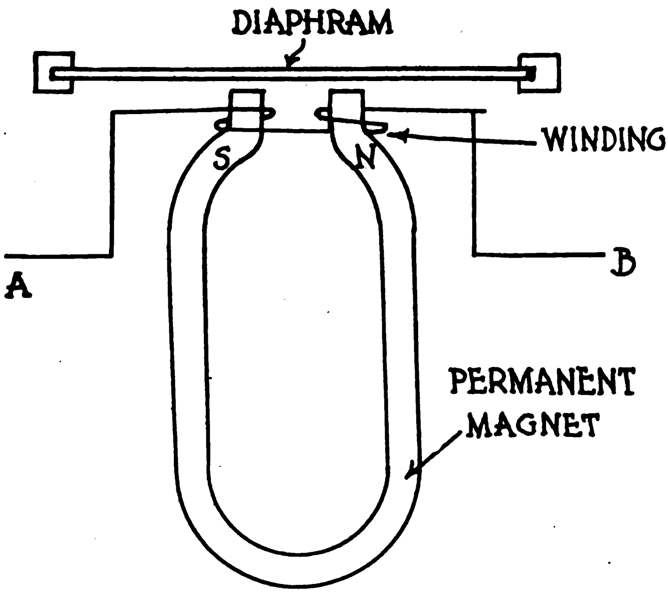

Fig. 25—Principle of Telephone Receiver

works. In Fig. 25, the essential features are shown. The main part is a horeshoe magnet above which an iron diaphragm or thin piece of sheet iron is held close to the poles or ends of the magnet. Now as a magnet always attracts iron or steel, the diaphragm will be drawn down toward

the magnet, but it is so designed that it is not allowed to touch the poles. We also have, wound around the poles of the magnet, two coils of wire, one on each pole, and through these coils varying currents are sent from the sending or transmitting portion of the telephone system.

Assume now, for example, that a current impulse is sent through the coils around the poles in such a direction as to strengthen the North and South poles by the magnetic effect that a coil has when carrying a current. This action was shown before in Fig. 4.

With the slight increase in magnetic action the diaphragm will be pulled down a little more than usual. If the current should now fluctuate so as to oppose or weaken the magnetic effect, the spring of the diaphragm would cause it to pull farther away from the magnet, so that a rapidly fluctuating current would produce rapid vibrations of the diaphragm, which would send out sound waves that could easily be detected with the ear.

The Watch-Case Receiver

The construction of the watch-case receiver, which is more compact and more suitable for our use, is shown in Fig. 26. This is the type that is used in pairs, one for each ear, and in this case the magnet is made small enough and of such a shape as to fit into the circular rubber case. Two

extensions or poles are fastened to the magnet proper, and serve to carry the magnetic effect up to the diaphragm. These poles or extensions also have the coils wound on them.

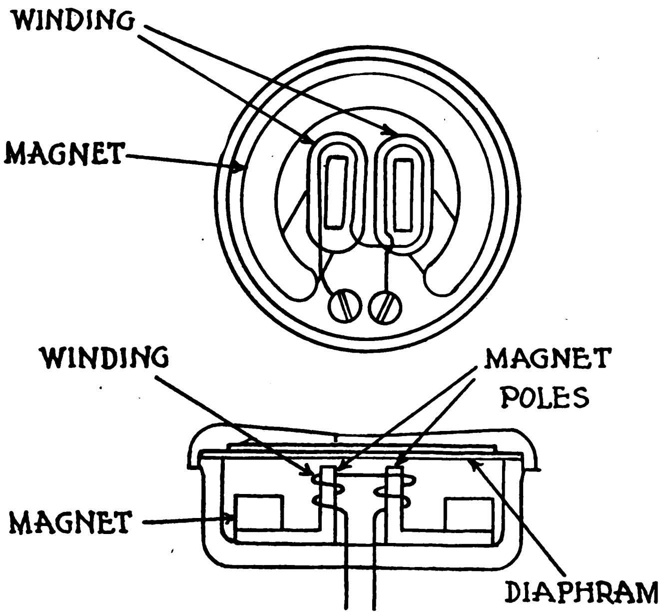

Fig. 26—Watch Case Telephone Receiver

High-Resistance Receivers Needed

The resistance of the winding in the receivers will depend on whether the coils have been made of fairly coarse wire and few turns, or whether very fine wire has been used, in which case each

coil would have very many turns. For ordinary telephone work the coils with the heavy wire are suitable, but for radio work the fine wire coils are needed.

The reason for the fine wire coils is that they naturally have more turns, and as the effect on the receivers is caused by the current and by the number of turns of the wire, it is highly important to have many turns, since the current is *very small.* The ordinary low-resistance receivers are, however, suitable enough in regular telephone service because the *currents are larger.*

Rewinding Receiver Coils for High Resistance

It often happens that in arranging a receiving set it may be desirable to rewind receivers that have low resistance and which can be purchased at a fairly low price, so as to make high-resistance receivers out of them. Ordinary low-resistance receivers are known as 75-ohm receivers, while those suitable for radio work are known as 2,000 to 3,000 ohm receivers. An ohm is a unit of resistance, such that a wire having a resistance of 1 ohm will allow 1 volt to send 1 ampere of current through it.

The method of winding that is the most simple is shown in Fig. 27, the wire to use being No. 40 enamel covered. One end should be soldered to the iron core or pole, and the turns should be put

on until the space is filled. The enamel must be removed with fine sandpaper wherever a connection is made. With this method of winding both

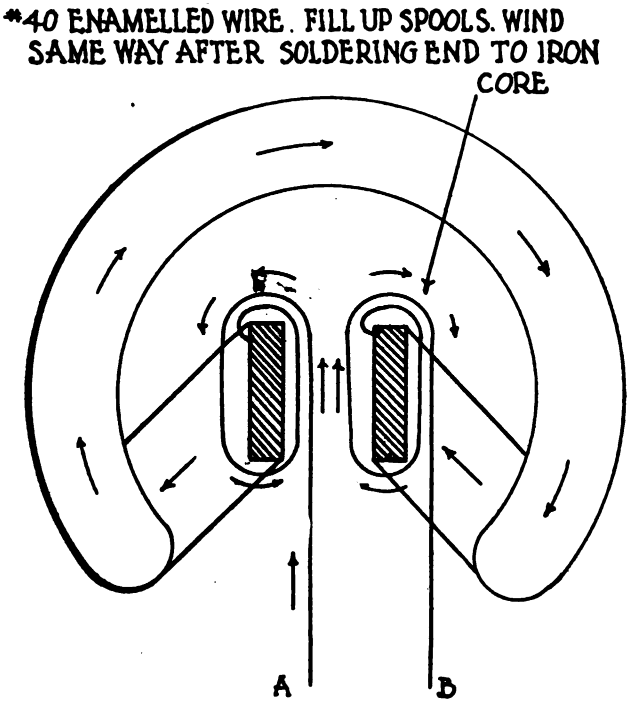

Fig. 27—Simple Way to Re-wind Watch-case Receiver

spools should be wound in the *same direction,* for on tracing the current from (*A*) to (*B*) in Fig. 27 we first travel in a *left-hand* or *counter-clockwise direction* around the pole at the left, which after

tracing through the first coil brings us to the magnet pole and then to the magnet itself. The magnet then completes the circuit around to the pole at the right, where the other coil is wound, and we now trace in a *right-hand* or *clockwise direction* from the inside of the coil out to the end of the circuit marked (*B*).

Current from (*A*) to (*B*) *must reverse around the two poles* so that this method gives us the correct result without bringing out connections from the inside of the coil, or figuring much about the direction of winding. The reason for the reversal of winding is that one coil affects a North pole while the other affects a South pole, and in order that their effects shall not be neutralized, this condition of winding is necessary.

Telephone Receiving and Sending

To understand what is happening in a radio system it is well to be familiar with the general principles of an ordinary telephone system. In Fig. 28 is shown a transmitter and receiver simply connected. Current is supplied by a battery, and goes out to the right and through the windings of the receiver, and through them, then over to the transmitter, where connection is made to the diaphragm which is vibrated by the sounds that come to the transmitter. Inside the transmitter is a quantity of granulated carbon, which makes a connection to a metal plate at the back of the

transmitter, from which the current returns to the battery.

Now the purpose of the granulated carbon is to vary the resistance of the circuit, for carbon has the property of lowering its resistance when tightly compressed, and of having a higher resistance when the contact pressure is slight. When talking into the transmitter, the sound waves of the voice will cause certain vibrations of the

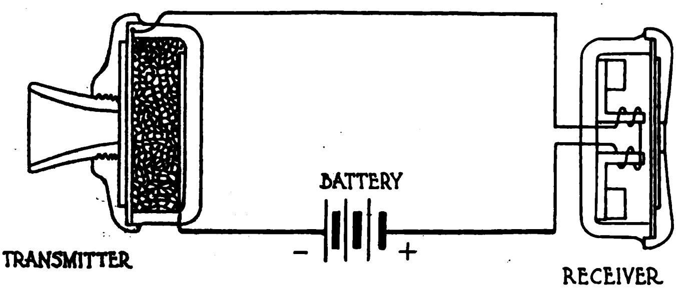

Fig. 28—Simple Transmitting and Receiving Telephone Receiver

fluctuation to take place in the flow of current in the circuit. These fluctuations, however, take place in the whole circuit, so that they cause a variation in the effect of the coils in the receiver, and attract its diaphragm more or less, thus reproducing the vibrations and hence the sounds that were sent into the transmitter. In similar fashion the radio waves transmitted through transmitting diaphragm, which will compress the carbon particles more or less, allowing a similar space cut through the wires of the aerial and pro-

duce a voltage which sends, with the help of the detector, the one-way current impulses through the receiving phones.

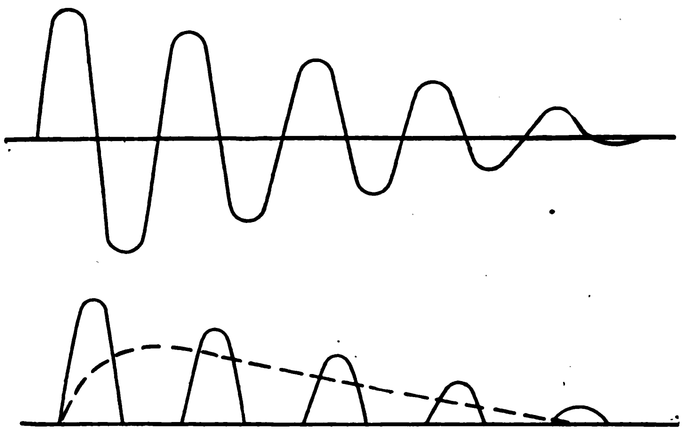

Fig. 29—Damped Wave as Sent and as Rectified by Crystal Detector

Receiving with a Damped Wave

In the upper sketch in Fig. 29 is shown a damped wave, which, without a detector, however, would have no effect on the phones, as the vibrations are at the rate of about a million a second, whereas the diaphragm in the phone is capable of vibrating only at the rate of about 10,000 per second. For this reason the wave has no effect. However, owing to the action of the crystal, only one-half of the wave is allowed to go through the phones, this portion being shown in the lower part of Fig. 29. Here again the diaphragm is not fast

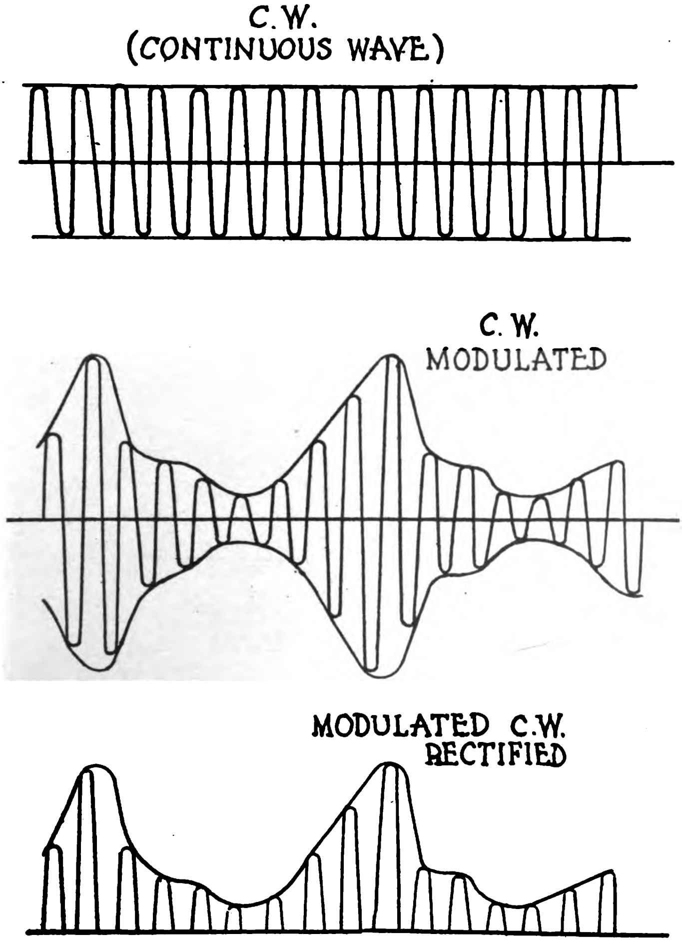

Fig. 30—Continuous Wave Modulated and Rectified by Crystal Detector

enough to follow each little wave peak, but as all the peaks are in the same direction they have the effect of one broader wave as indicated by the dotted line, and this produces a click in the phones.

The sending of wireless telegraph messages with 500-cycle current gives 1,000 alternations per second, which gives 1,000 of these dotted waves to the receiving circuit per second. This gives a high-pitched note in the phones which is easily distinguished from other sounds. Messages sent with code (or "dots and dashes") would then consist of longer or shorter series of these wave trains, which would produce a prolonged or short note in the receivers.

Wireless Telephone Messages

Reproduction of sounds instead of signals requires the use of the continuous wave instead of the damped wave. Such a high-frequency wave is shown in Fig. 30, the sketch at the top showing the plain wave. The second sketch shows the same wave modulated or changed by the action of the sending set, so that while the frequency remains the same, the amplitude or height of the different waves varies greatly. This gives the effect of an alternating wave, which, when rectified by a detector of some kind, produces the results shown in the lower sketch. As this wave is all in one direction through the phones, it gives variations

in the diaphragm which reproduce the sounds originally sent from the sending station.

Aerial Construction

Wire for the aerial may be copper, aluminum, or bronze. Iron wire is not so good, owing to its resistance, which "damps out" the oscillations or vibrations too quickly. Aluminum wire has the

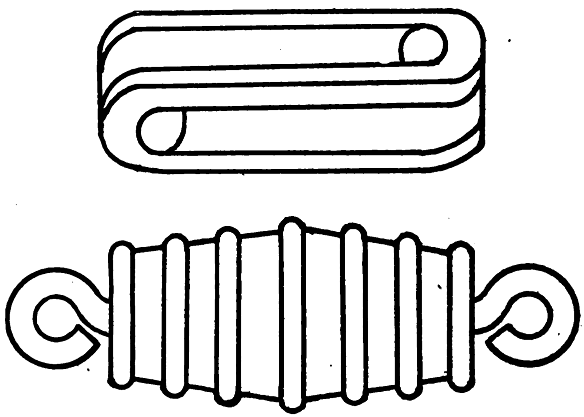

Fig. 31—Strain Insulators for Aerial

disadvantage of mechanical weakness. Bronze wire is probably the best of all. Moreover, the use of stranded wire is slightly better than solid wire, owing to the greater area exposed.

Good insulation is a prime essential, and almost any good porcelain will do for this purpose. In Fig. 31 are shown a number of commercial types

of insulators that are good for this purpose. The wires of the aerial are usually two or more in number, run in parallel, or side by side, with a connection at one end hooking them all together, this connection also leading to the receiving apparatus.

More about aerials will be given in Message 17.

MESSAGE NO. 9

"TUNING" THE CIRCUIT

In Message 8 we took up a simple receiving circuit, the diaphragm of which was shown in Fig. 22, but this method while simple has several serious disadvantages. The different units, however, are all entirely appropriate and will be illustrated in other circuits and their use in order to get better results will be shown. This simple scheme of connections does not permit of tuning to any particular wave length, or is not "selective," as it is called, nor can it receive over any great distance, owing to the fact that the impulses received go through the resistance of the phones and of the detector, and are therefore quickly damped out.

Why the Receiving Circuit Must Be Tuned

Referring to Fig. 22, it will be understood that the high-frequency magnetic oscillations cutting the aerial generate high-frequency currents flowing down to the earth and back again. As these flow through the wires, they produce magnetic circles around the wires, first in one direction and then in the other, as the currents reverse. These surging currents have a natural period, or frequency; just as a pendulum has a certain period of time in which it swings naturally, and in our

receiving circuit which includes the aerial, detector, phones, and ground, it depends on a number of things, such as the length and height of the aerial wires, location of surrounding objects, etc., which are so varied in different sets that we can never tell ahead of time just how the set will work.

That is one reason why we must be able *to tune the set,* while another reason is that if the natural period of our set is not just like the period of the sending station, we shall get very poor signals or none at all, and there is very little chance that the set would *happen* to be just right for the station we wish to hear.

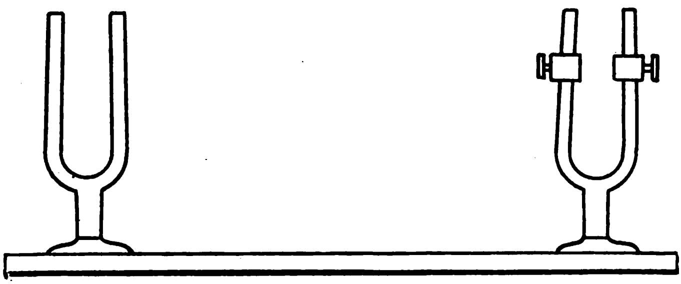

Fig. 32—Waves from Sending Fork Vibrate Receiving Fork When Properly Tuned

Tuning Forks Show Sympathetic Vibration

In Fig. 32 we have the illustration of two tuning forks and how one affects the other. At the left

is a fork that we may liken to a sending station, for if it is struck with a rubber or felt hammer, it will vibrate, at a certain frequency all its own, which is due to its construction. While it vibrates it will be *sending* out sound waves at the same frequency at which it is vibrating, and these will strike the other fork, which we may compare with the receiving station.

On the *receiving* fork we have two weights, which can be moved up or down, these having the effect of giving this fork a slower, natural vibrating period when they are up, and a faster vibrating period when moved down. Let us now assume that the sending fork is tuned to middle C and is therefore vibrating 256 times per second. Let us also assume that the weights of the receiving fork are so adjusted that it will also vibrate at the same rate. Then we shall find that the sound waves of middle C traveling through the air will hit the fork and set it vibrating, because the receiving fork is "in tune" with the sound waves that hit it. We should also find that if the weights on the receiving fork were moved up or down from this position, it could no longer be caused to vibrate to the waves sent out by the other fork.

The pendulum in Fig. 33 also shows the action obtained when impulses received are in tune with the receiving station. Let us forget the strip of paper for a few moments and first consider noth-

ing but the hammer and the pendulum. Assume now that the hammer is used to strike the pendulum a blow, as indicated in the sketch. The pendulum will be sent to the left, and, if no further

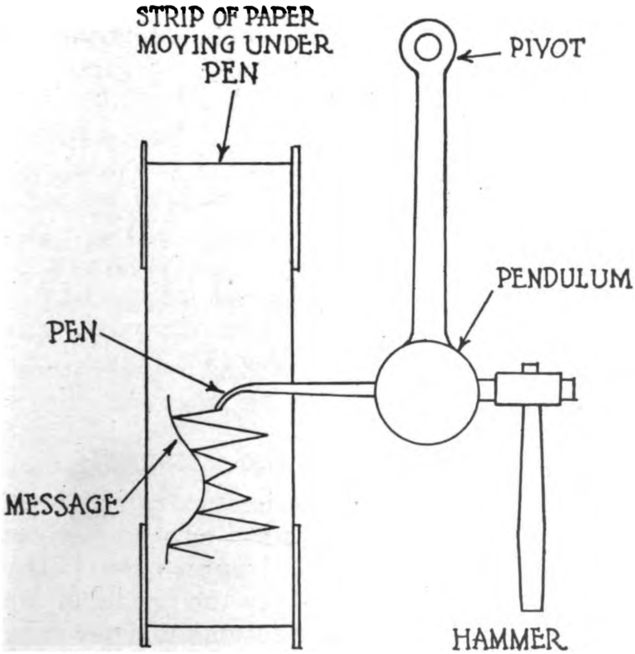

Fig. 33—Hammer Blows in Time With Swing of Pendulum Produce Greatest Effect

blows are struck, will continue to swing for a time at a certain period or frequency, *the frequency being affected by the weight of the pendulum.* Now assume that just as the pendulum naturally

swings to the left again, the hammer should again strike it, and that every time it naturally swung to the left, another blow should be struck. It is obvious that it would swing farther and farther each time, *because the receiving station* (the pendulum) *is in tune with the sending station* (the hammer).

Now let us suppose that, instead of the hammer and the pendulum being in tune, we should strike at the pendulum at any old time, perhaps starting it to swing, and the next time hitting it just as it was coming back instead of going. The force of the hammer would then be stopping the motion of the pendulum as much as starting it, and the swinging action would be very poor. *This would be like the receiving set that is not tuned properly.*

Receiving Messages with the Hammer

We will now construct an imaginary radio set, together with the hammer and the pendulum, by considering that they *are in tune* so that *slight* taps from the hammer will keep the pendulum going nicely. We will further assume that the hammer continues to strike *at the right time,* but with *varying force,* so that the swing varies considerably. If we now attach a pen to the swinging pendulum and let it trace lines on a strip of paper moved rapidly by means of rollers, we might trace out something as shown in Fig. 33, and by drawing

a smooth curve on the tips of the saw-tooth curve we might figure out the nature of the message being sent.

However, *what chance would we have* to receive such a message *if the swing of the pendulum was not in tune with the swing of the hammer?*

Tuning by Adding Weight

It is usually found that in most receiving sets the natural frequency is too great; in other words, the set is too fast for the messages that are to be received, so that some way must be found to slow down the natural period.

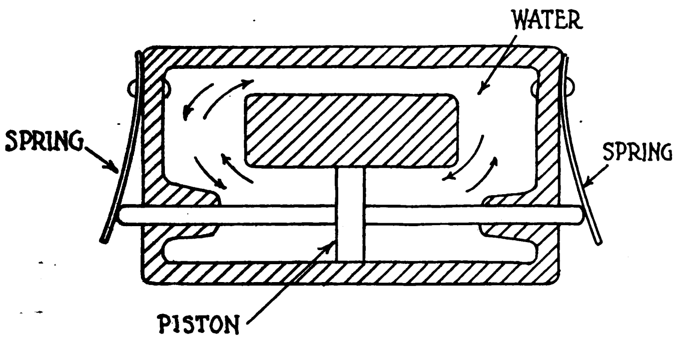

Fig. 34—Springs and Piston Produce Rapidly Oscillating Flow of Water.

In Fig. 34 we have a water illustration of an oscillating circuit, in which we will assume that the natural frequency is greater than we want it. In this illustration we have a piston in a cylinder.

Extending from both sides of the piston are rods which go through the casting and are held at their ends by flat springs, which, as shown, balance each other and there is no motion of the piston. Therefore the water which fills all the space inside the casting is also still.

Now assume, however, that a force is exerted on the right-hand spring, forcing it flat against the casting, so that the piston is forced to the left, and the left-hand spring is deflected twice the usual amount to the left. When the effect of the force at the right is gone, the spring at the left, being strained, will again force the piston to the right, and as it does so the water will whirl around to the left, or counter-clockwise, in the inner space. As the left-hand spring gets the water in motion, its inertia or momentum will carry the piston past the center position, again distorting the right-hand spring, and the action will be repeated, but in the other direction. This oscillating action will continue until the friction of the moving parts by its *damping* action has brought the piston to rest in its original central position.

We will now consider that this oscillating action of the water is wanted, but that it is going back and forth too fast for our purpose, and that we wish to slow it down. We will then consider the construction in Fig. 35, which is the same as in Fig. 34 except that the left-hand water passage is stopped up by a propeller, the shaft of which ex-

tends and carries a flywheel. Now as the piston is pushed to the left and the left-hand spring tries to send it quickly back again, the motion will be retarded because the flow of water is stopped by

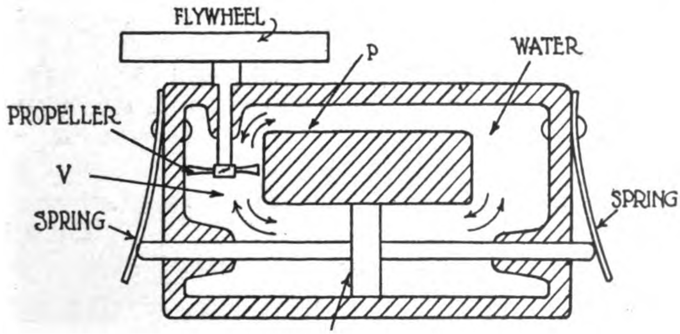

Fig. 35—Propeller and Flywheel Slow Down the Speed of Oscillations, or Reduce the Frequency

the propeller. The force of the spring, however, will be transmitted through the water and will gradually start the propeller and flywheel turning, and when it turns, the propeller will let the water get by, and the piston will be allowed to move, but much slower than before.

Now it might appear that the piston would merely move back to the middle position and stay there, but this will not be the case. For when it gets there, the spinning flywheel will push the water, and the water, in turn, will push the piston way over to the right again, so that the same oscillating motion that we had in Fig. 34 will take

place, *but much slower*. Thus, in order to tune or regulate the speed of the oscillations we should merely make the flywheel either heavier or lighter.

A Coil of Wire Acts Like an Electrical Flywheel

In the simple aerial circuit shown in Fig. 36 we have a tuning coil connected in the wire that leads

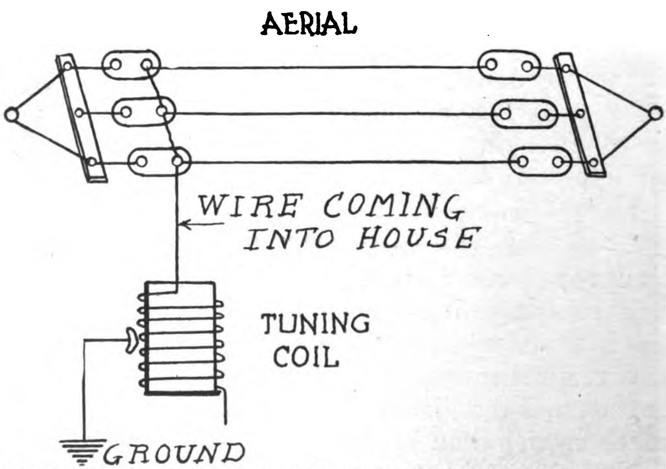

Fig. 36—Coil of Wire in the Circuit from Aerial to Ground Slows Down Oscillations, Giving Lower Frequency and Greater Wave Length

from the aerial to the ground, and in connection with it we have a sliding contact so that the number of turns in use can be changed as desired. The question will naturally arise how this can possibly

change the natural period with which the currents surge from the aerial to and from the ground.

Let us take first the case where there is a current rushing to the ground. Of course, in order to get there it must pass through a number of turns in the tuning coil. As it does so, it will produce a magnetic action in the coil, as we learned from Fig. 4. Now this magnetism springing up in the same coil that produced it will generate a voltage, which we call self-induced voltage, or the voltage of self-induction. This was illustrated in Fig. 9 where one coil induced a voltage in another, but it does not make any difference what makes the magnetism; if it springs up in a coil, a voltage will be induced.

Now this voltage of self-induction has a peculiar effect in that it *always opposes* the action that produced it, and as the current was surging down to ground this induced voltage was acting in the *opposite direction* and slows down the rushing current. Then when the current rushes up again, the coil again has a contrary action, so that no matter which way the current tries to flow, the tuning coil always has a retarding action.

Another peculiar action of the tuning or induction coil is that when the current is flowing this coil does not want to let it stop flowing, so that it does not damp out the oscillations, but merely reduces their frequency, so that we might think of it as *an electrical flywheel.*

Using the Single-Slide Tuner

In Fig. 36 we had a theoretical method of tuning the receiving circuit, but we had no phones to receive with. These are shown in Fig. 37, connected across the tuning coil, and operated by the voltage or electrical pressure across this coil. Now it may appear as if there would be no pressure at these points, so for an illustration, let us again refer to Fig. 35 and consider the action that takes place as the piston is at the extreme left, and the left-hand spring is just starting to exert its full force to push the piston back to the right. This will push the water so as to pile up pressure at the place marked (*P*), which is just above the propeller, while the motion of the piston to the right will try to produce a lack of pressure or vacuum just under the propeller at the point marked (*V*). There will therefore be a considerable difference of pressure on the two sides of the propeller.

In the same way the rush of current down from the aerial will pile up at the tuning coil, so that there really will be a considerable difference in voltage between the two ends of the coil. This causes surges of current to go through the detector and the phones in one direction, the detector killing by its peculiar action the surge of current in the other direction.

Now the theoretically perfect tuning that we might have had in Fig. 36 is thrown out somewhat by the connection of the phones and detector, as

shown in Fig. 37, and it is found that the results thus obtained can be very much improved by using a tuner with a double slide, and connecting as shown in Fig. 38. Here the phones are connected to a slider that connects the phone and detector

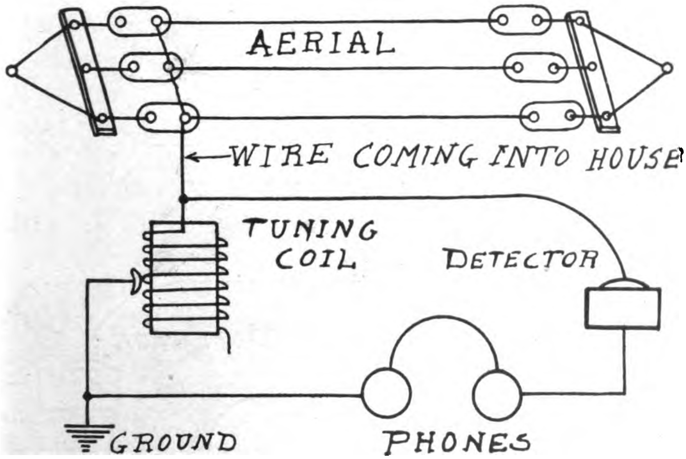

Fig. 37—Receiving Circuit With Single-Slide Tuner.

circuit across a few more turns than are in use in the circuit from aerial to ground, thus giving a little higher voltage in the phone circuit, and producing clearer results.

This higher voltage results from the fact that when the magnetic action is produced in the tuner by the surging current, it induces voltage in each turn of the coil, so that it is quite natural that the voltage should be increased by increasing the number of turns in use.

Making a Two-Slide Tuner

The making of a two-slide tuner is not a very hard job, a construction that is satisfactory being shown in Fig. 39. A tube is required about four inches long and from three to four inches in diameter. The best material for this is mica, but it is

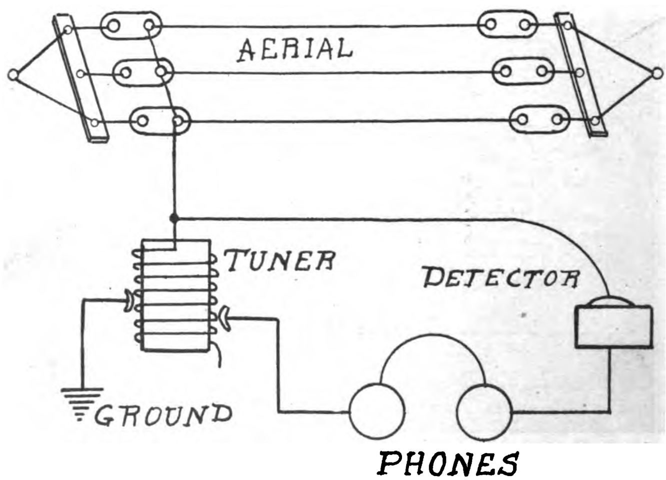

Fig. 38—Receiving Circuit With Two-Slide Tuner

also quite expensive and hard to get. Fiber is not very good, as it may contain some moisture. The next best material to mica is cardboard, which should however be treated to prevent its absorbing moisture.

For treating the cardboard and for holding the wire on after the tube has been wound, a solution

of water glass should be used. This is but another name for sodium silicate, which can be obtained at the drug store, and can be thinned out with water to form a sort of glue or mucilage. The tube should be coated and allowed to dry, and then the wire should be carefully wound on, so that the turns are side by side, and do not cross each other.

The size of wire to use may be anywhere from No. 18 to No. 25, and should be insulated. This insulation is effected either by coating the wire with enamel, or it is silk covered, or single cotton covered (S. C. C.), or double cotton covered (D. C. C.). Double cotton-covered wire is better than single.

The tube will be supported on a standard having a base and two end pieces, as shown in Fig. 39, and a support for the tube can be made by sawing out a circular piece of wood just the right size to slip inside the tube. This will then be glued to the end bracket, as shown at the lower right-hand sketch in the figure.

The sliders are made of spring brass bent around a square brass rod, a good size of rod to use being 3/16 inch or ¼ inch square. In order that the sliders can make contact with the winding, it is necessary to remove the insulation. This can be done after the coil has been treated with the water-glass solution, by using a fine, sharp file,

and filing the insulation off just where the sliders will come.

In the upper view in Fig. 39 one brass rod is shown on top of the tuner and the other is shown at the side, while at the lower end the winding begins at a binding post which is due to be connected to the aerial and the detector, as shown in the sketch in Fig. 38. The center brass rod then is connected to a water pipe or radiator, while the one at the side is connected to the phones.

How to Bend Brass without Breaking It

In making a slider, it may be found that the spring brass will break when bending it around a sharp corner. To overcome this, the brass should be heated in a flame, such as is obtained from an ordinary gas stove, until slightly red. It should then be plunged in water. It will then be found soft enough to bend around a sharp corner without breaking. After being shaped, hammering will restore its springiness.

In case it is desirable to buy the various parts for a two-slide tuner receiving set, the following list may prove of assistance:

Two-slide tuner.

Crystal detector.*

*While the set indicated above will give fair results, and it is possible to use it up to 25 miles from the receiving set, the reader should also consider the audion bulb set described in Message No. 18, which not only gives clearer messages but from much greater distances.

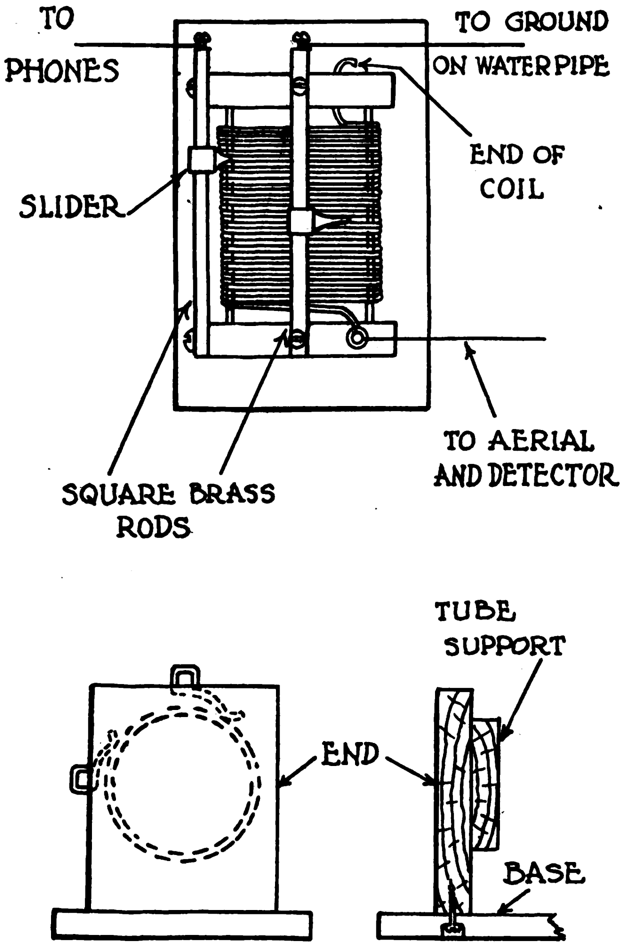

Fig. 39—Simple Construction for a Two-Slide Tuner

Pair of receivers or phones; these should be wound from 2,000 to 3,000 ohms; 2,200 ohm or 2,400 ohm receivers work very well.
About 100 feet of stranded aerial wire; the exact amount will depend on the room available for suspending the aerial. (See Message No. 17.)
Two or more insulators for the aerial, depending on the way it is supported.
A few pieces of wire for making connections.

Connect as shown in Fig. 38 or as indicated in Fig. 39A, the latter figure also showing the buzzer connection for testing the crystal.

Testing the Crystal

The crystal, while simple in operation, has one peculiar feature in that there are certain spots that are more sensitive than others. Some places on the crystal may be practically dead, while other spots may be very good. In other cases the whole crystal may be no good, there being practically no sensitive spots on it. For this reason it is best to buy a tested crystal if possible. Before trying to tune up our set to catch any particular message it is therefore necessary first to test the crystal to see that it is working as it should.

When two ways of making a detector were described and illustrated in Fig. 24, the construction was made such that it would be easy to change the point of contact of the "cat whisker" with the crystal, so that a sensitive spot might more

easily be located. Referring now to Fig. 39A, we have not only the two-slide tuner of Fig. 39 wired up with the other parts of the set, but we also have shown an extra wire (*X*) connecting from the door bell or buzzer circuit in the house to the receiving circuit. This wire is connected from *any* part of the buzzer circuit, but is best connected to the aerial terminal of the two-slide tuner. Operating the push button will now work the buzzer and give a note in the phones if the crystal is operating on a sensitive spot.

While an ordinary buzzer will do, it is best to doctor it up a bit so that it will vibrate very fast and give a high-pitched or squeaky note, not a low tone or a low-pitched note. This can be done by tightening the spring on the buzzer, or by putting a U-shaped piece of thin cardboard between the vibrating armature and the pole piece which attracts it. This will have the same general effect as the increase in spring tension, and will give a note easily heard in the phones.

With the buzzer in operation, and preferably at such a distance that it cannot be heard in the ordinary way, the phones should be put on the head, and the location of the "cat whisker" on the crystal changed until a clear sound is heard. The detector should then be carefully let alone so that the adjustment will not be disturbed, and the set is now ready to be tuned.

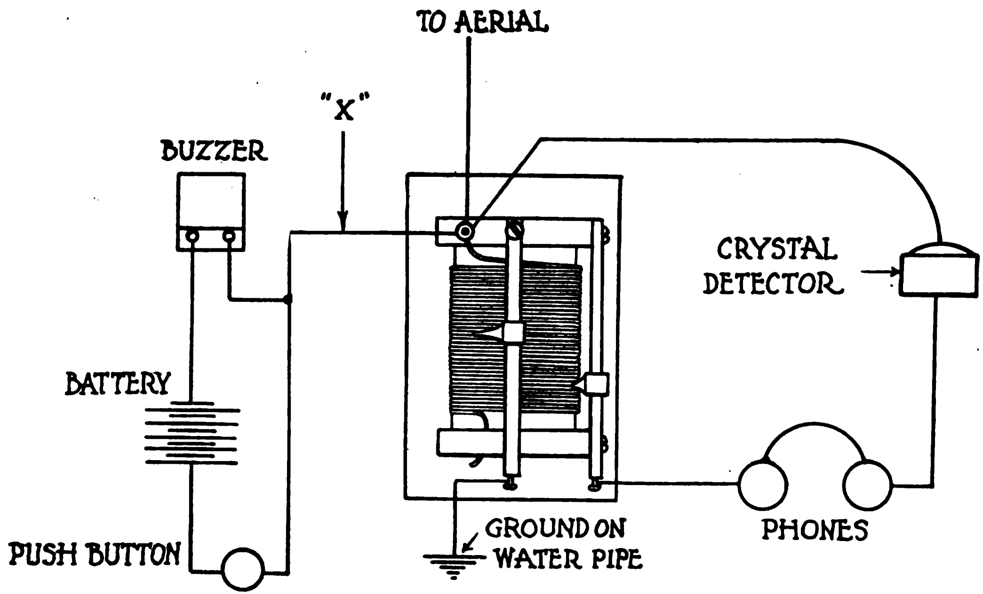

Fig. 39A—Circuits for Testing the Crystal Detector

Tuning the Two-Slide Crystal Receiving Set

Referring to Fig. 39A again, the wire (*X*) can be disconnected after the detector has been checked as outlined above, and the two sliders can both be moved away from the aerial terminal as far as they will go. While listening, the center slider, which controls the number of turns in the circuit from aerial to ground, can now be pushed upward or toward the aerial terminal to see if messages are heard. If no results are obtained over the whole length of the slide, the slider at the right should be pushed up from 1/8 inch to 1/4 inch, and the center slider should then be tried again over the whole length of its track. This process should be repeated for every slight difference in the position of the right-hand slider, until results are obtained.

If no results are obtained when it is known that broadcasting or other messages are in the air, the detector should again be checked, for, being the most sensitive part of the apparatus, it is possible that it has been disturbed and is out of adjustment. On account of the possibility that frequent tests on the crystal may be advisable, it is a good idea to have a buzzer and dry-cell battery installed where they can be readily used for this purpose.

MESSAGE NO. 10

THE CONDENSER AND WHAT IT DOES IN RADIO RECEIVING

Would you like to use a radio set without the slightest idea as to what makes it work? The answer is *no*, or you would not be reading this book.

In all radio sets, we find condensers, or at least condenser action, even if the actual condenser is not seen. Then if you really want to know how the radio set works you should carefully read the following explanation of the condenser. It is as essential to the radio set as the mainspring is to the clock.

What is a condenser?

A condenser is an electrical spring. (See Fig. 40.)

What can a condenser do?

Absorb a shock or an electrical jolt, even as a spring absorbs a mechanical jolt.

When a spring is loaded, what happens?

It deflects or bends and is strained internally.

When a condenser is electrically loaded (charged), what happens?

It is also strained electrically, but we do not see the effect with the eye as in the case of the spring.

If too great a load is put on the spring, what happens?

It breaks.

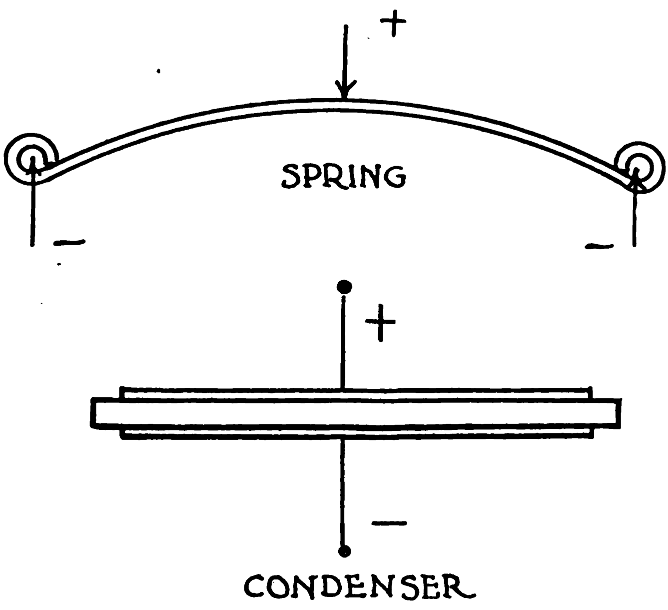

Fig. 40—Simple Condenser; Its Action Compared to that of a Simple Spring

If too great an electrical load (voltage) is put on the condenser, what happens?

It breaks down (punctures) the insulation, showing a burned place.

What is a condenser made of?

Two pieces of metal separated by insulation.

When the spring is released from its load, what happens?

It rebounds or springs back to its original shape, and the internal strain is relieved.

When the condenser is released from its load, what happens?

It rebounds (electrically). We commonly say it discharges, and the strain on the insulation is thus relieved.

How is a condenser charged and discharged?

By connecting to a source of voltage, it is charged.

By disconnecting from the source of voltage and connecting its terminals together with a piece of wire, it is discharged.

What is the capacity of a condenser?

Its electrical elasticity, or springiness.

Is this the same as its insulation strength?

No, the greater the capacity, or electrical elasticity, the less its electrical insulation strength.

If the spring is made thicker, what happens to its elasticity?

It is made less.

If the insulation in a condenser is made thicker, what happens to its capacity or electrical springiness?

It is made less.

If the spring is made longer, what happens to its elasticity?

It is increased.

If the condenser is made longer, what happens to its capacity?

It is increased. Here the illustration is not perfect, for an increase in the width of the condenser will also increase the capacity, the capacity being proportional to the area, and inversely proportional to the thickness of the insulation.

MESSAGE NO. 11

OSCILLATING CURRENTS USED IN RADIO RECEIVING DEPEND ON BOTH CONDENSER ACTION (ELASTICITY) AND ON INDUCTANCE OR THE MAGNETICALLY GENERATED VOLTAGE IN A COIL, WHICH GIVES THE EFFECT OF MOMENTUM

We have previously considered how the current flowing in a coil of wire has a magnetic effect, which generates a voltage which we said was due to self-induction, the effect being to keep the current flowing, so that it seems to act like a flywheel. A mechanical and hydraulic illustration of this action is shown in Fig. 41, where we have a piston moving in a cylinder, the water passage connecting with another chamber at the right in which there is a rubber diaphragm which prevents continuous flow in either direction.

Similarly, in Fig. 42, we have a coil of wire or an inductance coil connected to a condenser, the insulation of which would prevent continuous flow of current in either direction. Now suppose that in Fig. 41 we should give the piston rod an upward push and release it. The push would send the water around to the right, this motion being possible owing to the rubber diaphragm which would spring down to position (*A*), while the piston would be in its position (*a*). When the force had spent itself, the internal strain in the

rubber would begin to exert itself, and the water would be pushed around to the left again, forcing the piston down. When the piston reached its

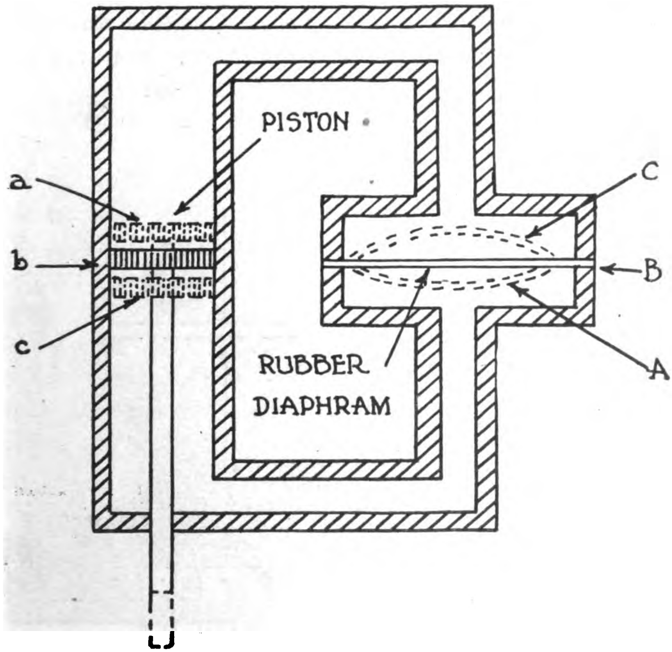

Fig. 41—Oscillating Current of Water Produced by Weight and Spring Action of Diaphragm

position (b) and the rubber its position (B), however, we should have the piston and water moving at a fair rate of speed, and this weight or momentum would carry them past the middle position to the positions (C) and (c). The rubber would

then again spring back and the oscillating action of the water would continue, with the degree of motion becoming gradually less, until it would finally come to rest at the middle position, owing to internal friction of the moving water and piston. Another push on the piston would give another series of oscillations, however.

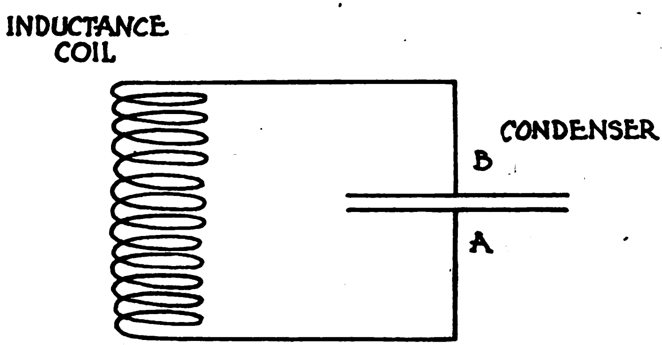

Fig. 42—Oscillating Electrical Current Produced by Inductance (Weight) and Condenser Capacity (Elasticity).

In Fig. 42 we will now assume that a bar magnet has been suddenly pulled out of the inductance coil at the left. We know from our previous discussions that this will generate an electrical voltage, which we will say is in such a direction as to make side (*B*) of the condenser positive and side (*A*) negative. As soon as the first rush of voltage has spent itself, however, and there is no longer voltage generated in the coil, the elastic effect of the condenser will assert itself, and it will dis-

charge, the discharge current flowing around through the coil to the (A) side of the condenser. As soon as the condenser has reached a discharge condition, the circumstances will be similar to those in the middle position in Fig. 41, for the electrical current through the coil will be rushing along at a rapid rate, and owing to its flywheel effect (inductance), it will not want to stop. The result is that it keeps going and has the effect of now charging the (A) side positively and the (B) side negatively. When the rush of current in this direction is spent, a reverse flow occurs, and this oscillating electrical current continues, until it too dies out, owing to electrical friction (resistance) in the circuit.

Suppose now that the inductance (flywheel effect) and the capacity (spring action of the condenser) would be just right, so that the current would oscillate 1,000,000 times in a second, then we should have the circuit tuned to a 300-meter wave, for you will remember that a 300-meter wave is produced by a frequency of 1,000,000.

Tuning an Oscillating Circuit

The question of tuning an oscillating circuit in radio receiving may be compared to the action of a springboard loaded with a weight, as indicated in Fig. 43. Here we have shown a board firmly anchored in a brick wall, while the free end has cast-iron weights bolted to it. If we

should now bend the board down from its middle position and then release it, the board would spring back and forth between the dotted positions.

Now the speed at which it would oscillate would be reduced very much by increase in *either* weight

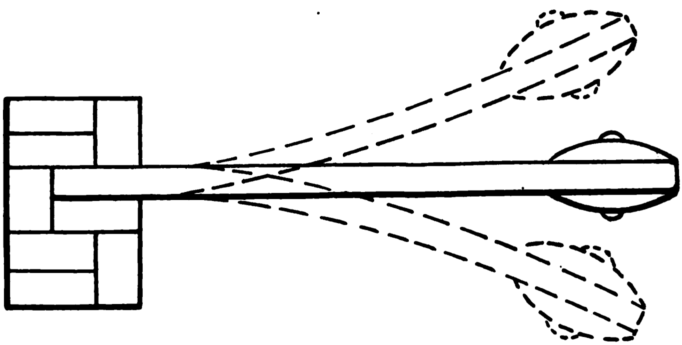

Fig. 43—Tuning (Rate of Oscillation) Depends on Weight and Elasticity

or springiness, a long, thin board swinging much more slowly than a short thick one; increase in weight would also make it go slower, while entire removal of the weight would give very short, quick vibrations, the weight of the board itself making these possible.

Electrical Tuning

In our circuit in Fig. 42 the same conditions hold, for the greater the capacity of the condenser, the slower the circuit will oscillate and the longer

the wave length to which we shall have it tuned. In similar manner the greater the inductance of the coil, the slower will be the oscillations, so that increase in either the coil or the condenser will increase the wave length.

This same oscillating action occurs in the two-slide tuner set, the circuits of which are shown in Fig. 38. In this case there is a condenser acting, although it does not appear as such.

The "ground," being a conductor, is one side of this condenser, and the aerial, also being a conductor, is the other part, while the air in between is the insulating material. The aerial circuit through the tuning coil to ground, therefore, includes both inductance, or electrical weight or momentum, and condenser capacity or electrical springiness.

MESSAGE NO. 12

LOOSE COUPLING, AN IMPROVEMENT OVER THE SINGLE CIRCUIT FOR RECEIVING

The last practical receiving circuit that was illustrated was shown in Fig. 38, where a two-slide tuner was used. Even in this circuit, however, a large amount of the energy received from the aerial is used to operate the phones, so that an improvement can be had by putting the phones in a separate circuit from the antenna circuit.

Such a simple circuit is shown in Fig. 44, where our tuning coil is now called the primary ("primary" meaning first) because it first gets the impulses from the aerial or antenna. The secondary is a similar coil slightly smaller, which is located inside of the primary, but does not have any metal connection with it. For the sake of clearness it is shown alongside, although really inside of the primary.

From our previous discussions you will remember that the currents from the antenna or aerial to ground are alternating very rapidly, and that in going through the coil of wire that we call the primary they produce magnetism, first one way and then the other. You will also recall that rapidly changing magnetism produces electrical voltage, when it cuts through the turns of a coil. It is for this reason that the changing currents in the primary set up similar currents in the sec-

ondary which surge back and forth, charging the condenser first one way and then the other, as illustrated in Fig. 41 and Fig. 42.

Now when the condenser is thus charged first in one direction and then the other, it of course has a voltage or electrical pressure across its terminals, so that if we connect our phones and detector as shown in Fig. 52, we shall get the message received by the aerial.

Tuning the Primary Circuit

Any aerial circuit will have both inductance or flywheel action and capacity or elasticity or electrical springiness. The inductance is due to the magnetic lines of force which form around the wires with the ocillations in current, while the condenser effect is due to the fact that the aerial is one conductor or set of wires while the earth is another conductor, and in between is the air, which is an insulator.

This gives the aerial circuit a natural frequency which might be right for one wave length, but is not likely to be exactly right for the one in which we are interested. Fig. 44 shows the primary circuit as having a single-slide tuner, so that the inductance of the antenna circuit can be varied. With the slide at the top, as shown, it would be tuned for long waves, and at the bottom with the turns all cut out of the circuit it would be tuned for the shortest waves possible to get with that set.

Tuning for Long Waves

In Fig. 44 it might be sometimes the case that even with all of the turns in the circuit, the set might not be tuned for the longest waves that were

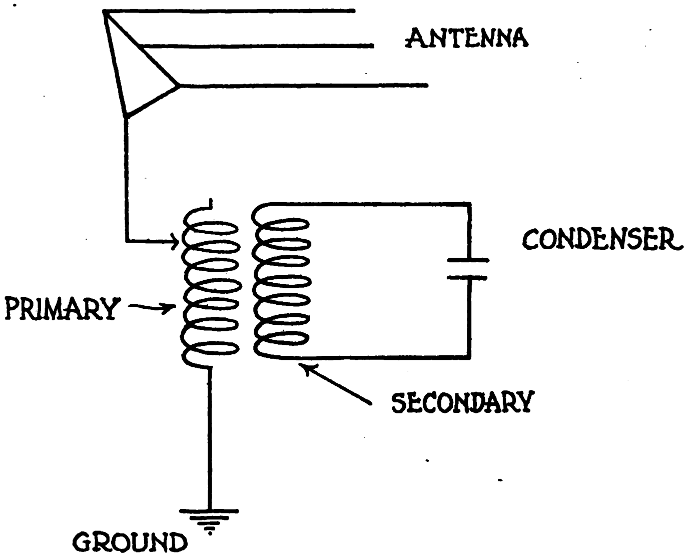

Fig. 44—Loosely Coupled Circuits, Oscillating Currents in Secondary Produced by Magnetic Effect of Primary Oscillations

to be received. In this case it would be possible to add another coil, as shown in Fig. 45. This will have the same added effect as though it were the same number of increased turns in the original tuning coil, and the variation in turns can be made

in the first coil. This is like adding electrical weight to the circuit to make it slower.

Another way of accomplishing the same result is to add a condenser or electrical spring to the circuit, as shown in Fig. 46. This also makes the circuit slower and tunes it to longer waves.

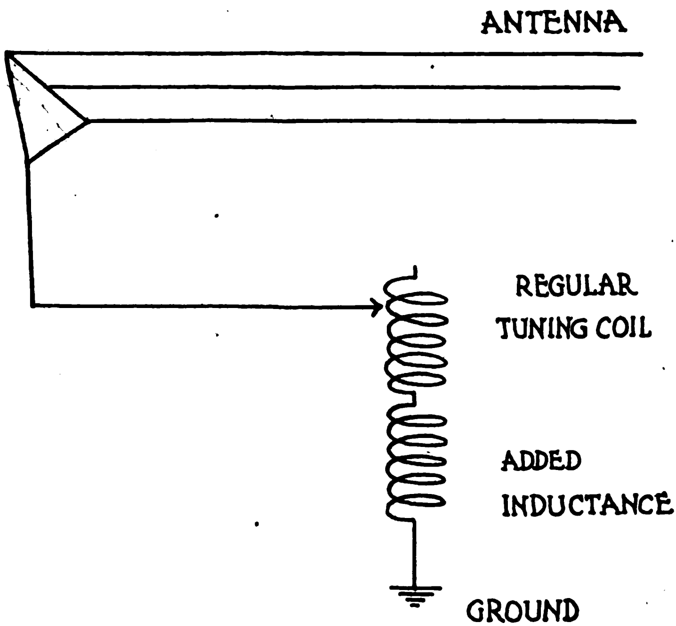

Fig. 45—Tuning for Longer Waves by Adding Inductance

Tuning for Shorter Wave Length

It sometimes happens that the natural wave length of the antenna circuit is too great, even

with all the turns cut out of the tuning coil, and in this case it is possible to put a condenser in series with the circuit, as shown in Fig. 47, a switch at the side being used to short the condenser out, when longer wave lengths are desired. We could of course disconnect the condenser which was added in Fig. 47, and put the lower connection from tuning coil back on the ground or water pipe again, but this would not be convenient. The shorting switch is therefore used, as shown, because it makes a good connection from the tuning coil to ground, and when it is closed, the connection is so good that the condenser will have no effect, so it is just as good as actually removing it. This is because the condenser has insulation in it between one side and the other, while the switch is a conductor or carrier of electricity, and is such an easy path for the current compared with the condenser that we call it a short circuit, the shortest way being the easiest way—for electricity at any rate.

Therefore when we want the condenser to act we leave the switch *open* and when we do *not* want the condenser to act we leave the switch *closed.*

The action of the condenser is just the opposite of the one in Fig. 46, owing to the different way it is connected. The way that these different variations affect the circuit will now be illustrated by our old spring-board sketch with slight changes, as shown in Figs. 48, 49, 50, and 51.

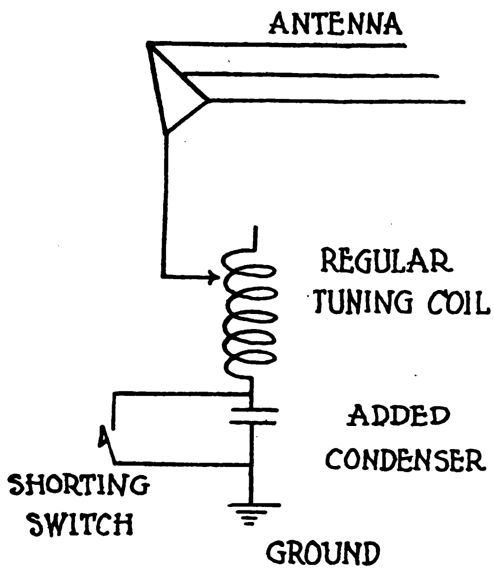

Fig. 47—Tuning for Shorter Waves by Adding a Condenser in Series (Same Electrical Path) With Regular Tuning Coil

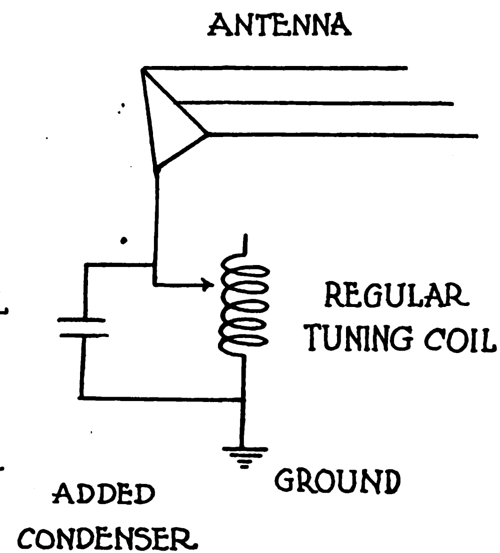

Fig. 46—Tunning for Longer Waves by Adding a Condenser in Parallel (Alongside) of Regular Tuning Coil

Tuning Methods Illustrated with the Spring Board

In Fig. 48 we have our regular spring board, which we will say is set in a block of concrete, but is loose enough so that it can be slid back and forth if desired, to increase or decrease the working length of the board. As shown in Fig. 48 we will say that it illustrates the electrical action of

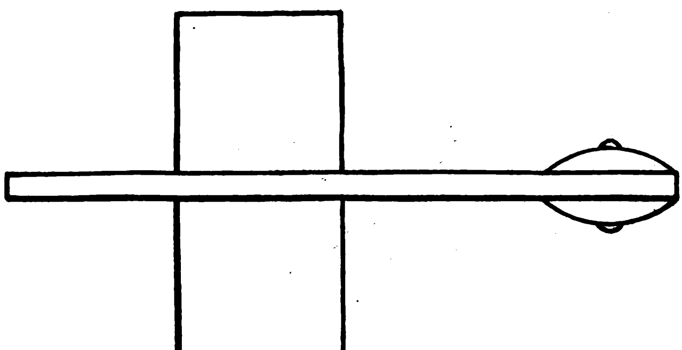

Fig. 48—Illustrates Action of Primary in Fig. 44

the primary in Fig. 44, where some tuning is possible by changing the size of the weights (or electrically changing the number of turns of wire in use in the coil).

Fig. 49 shows that another weight has been added which corresponds to the addition of the extra coil as shown in Fig. 45, which will slow down the action, giving longer waves. In Fig. 50

we have attained the same results as in Fig. 49, but by a different method, for instead of adding weights, we have pulled the board out through the concrete block so that a longer section of the board is contributing to the spring action, and with the same weight the motion will be slower and the wave length therefore longer.

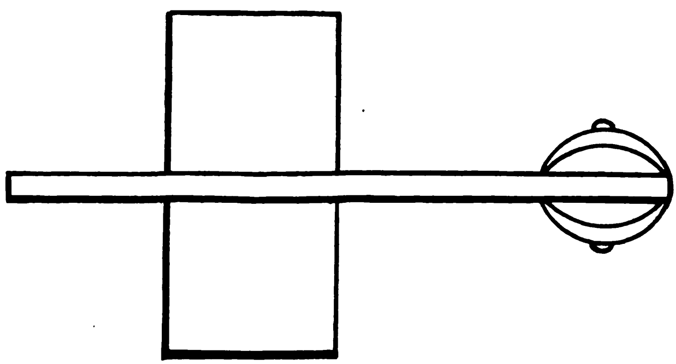

Fig. 49—Illustrates Adding Inductance (Weight) as in Fig. 45

Now compare with this increased springiness the illustration in Fig. 51, where we have again added springs, but in such a way as to *stiffen* the action instead of to increase it. This gives a faster rate of vibration and therefore a shorter wave length, for these springs are *in series* or in the path of the motion, even as the condenser in Fig. 47 was in series or in the path of the aerial current flowing to and from the ground.

Tuning the Secondary

For best results it is not only necessary to have the primary in tune with the waves to be received, but the secondary must also be in tune in order that its currents will continue to oscillate and give a clear message. For this reason the circuits shown in Fig. 52 are not as good as those shown in Fig. 53, where not only the primary turns can

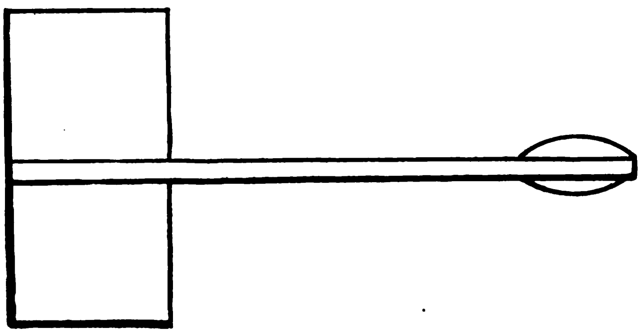

Fig. 50—Increased Flexibility; Illustrates Adding Condenser in Fig. 46

be varied, but the secondary turns can also be changed by the taps or connections brought out to a regulator, from every few turns in the coil.

In addition to this adjustment, the condenser is made variable, this being indicated by the slanting line drawn through it. As it is not desirable to use an excessive condenser effect, it is usually employed to tune in between the taps of the regulator. For example, we might start by setting the

regulator at its first tap, and changing the condenser back and forth. Then set the regulator at the next tap, and again work the condenser, this process being repeated until the clearest results are obtained.

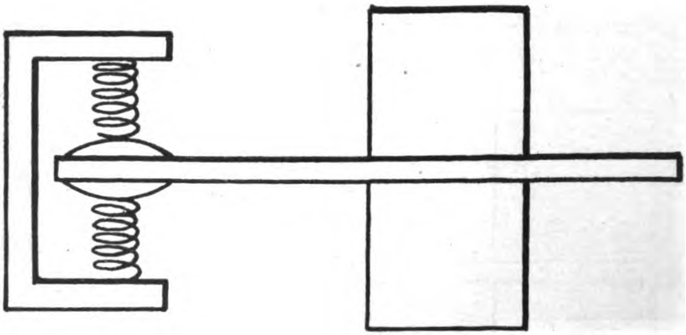

Fig. 51—Stiffness Due to Added Springs; Illustrates Effect of Condenser in Fig. 47

The condenser shown by the dotted lines as connected across the phones may or may not be used, although it does produce a slight improvement, the action being to collect the very rapid half-waves that are sent through the detector, and release them as one wave to the phone.

Close Coupling, a Common Mistake

In the circuit shown in Fig. 53, the secondary is so constructed that it can be inserted more or less into the primary, somewhat after the fashion

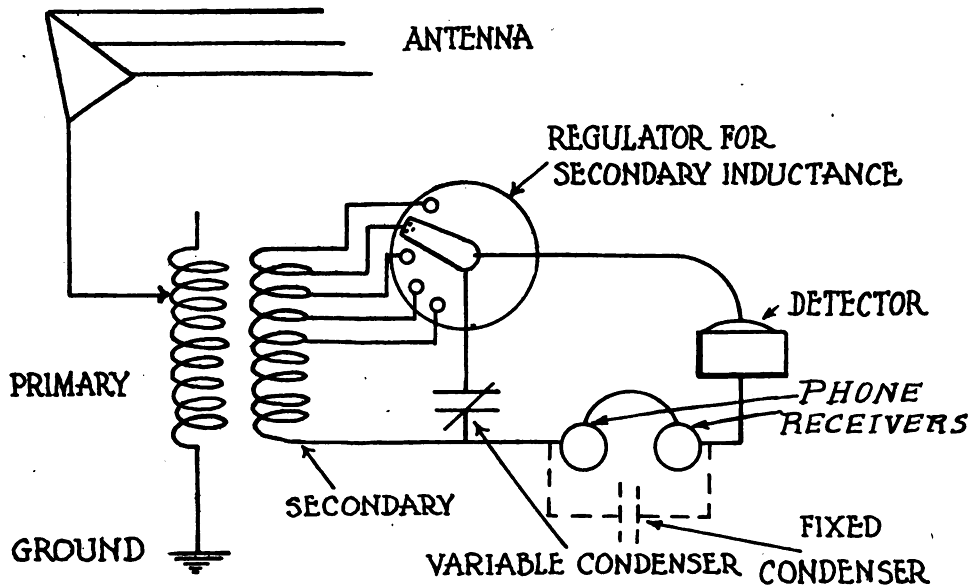

Fig. 53—Loosely Coupled Receiving Circuits With Variable Primary and Secondary Inductance and Variable Condenser in the Secondary Circuit

of a telescope. Close coupling is accomplished by pushing the secondary all the way in, which, while it gives powerful results, *does not give clear results.* On the other hand, pulling the secondary part way out will not transfer as much energy to the secondary circuit, but the wave form will be better and the message more distinct.

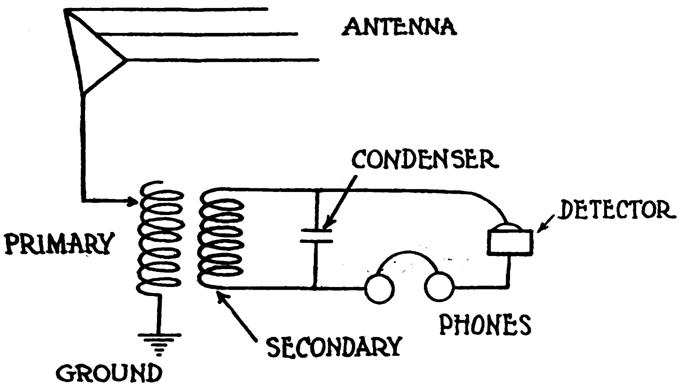

Fig. 52—Loosely Coupled Circuits With Phones and Detector in the Secondary Circuit

This is all due to the interference or mutual effect that the currents in each circuit have on each other, for each has its own magnetic action, and each magnetic change will produce voltages in the coils of wire. This mutual action is well illustrated by the very simple experiment shown in Fig. 54. Here we have a cord strung loosely between a couple of pegs or nails, and on the cord are two

more cords or strings on which weights are suspended.

The experiment is to allow one weight to hang straight down. Then take the other weight and start it swinging. We will assume that the sec-

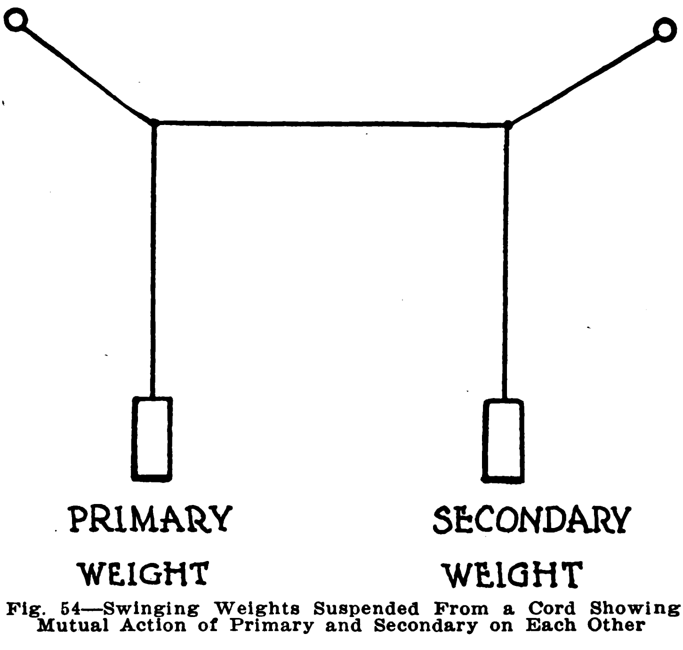

Fig. 54—Swinging Weights Suspended From a Cord Showing Mutual Action of Primary and Secondary on Each Other

ondary weight is allowed to hang straight down and that the primary weight is started swinging back and forth. Then if the action is carefully watched, it will be seen that the primary weight

starts to swing less and less, and that the secondary weight has begun to swing. Soon the secondary will be swinging widely and the primary will be standing still. Then the motion will again be transferred slowly back to the primary which will soon be in full swing, while the secondary has again come to a standstill. This action will be repeated for a long time, first one weight and then the other taking up the motion, which illustrates in a general way the transfer of oscillations from one electrical circuit to another.

Loose Coupling

On account of the interference illustrated above it is best to have the secondary loosely coupled with the primary, that is, pulled out as far as possible consistent with good results, the best position of course being one that must be obtained by experiment.

MESSAGE NO. 13

HOW TO MAKE A LOOSE COUPLER

In Message No. 12 and in Fig. 53 the use of the loose coupler was described, and its circuits were

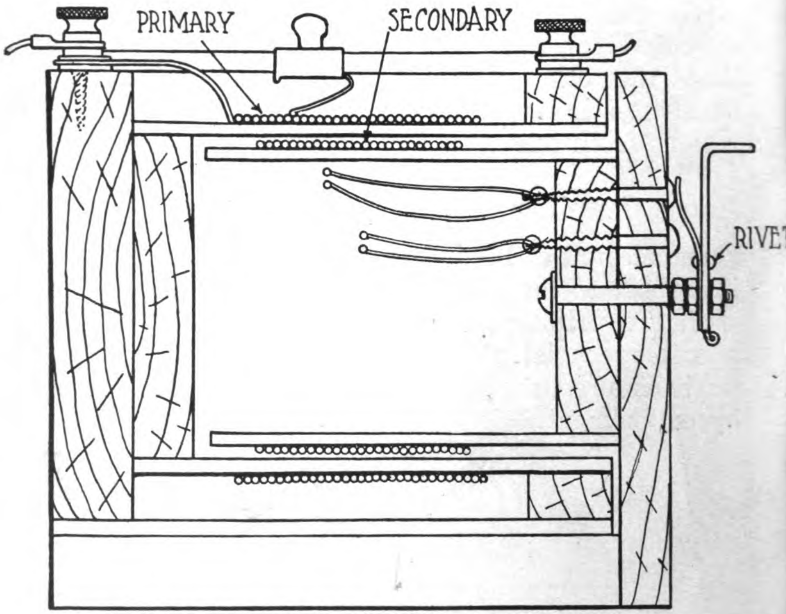

Fig. 55—Sectional View of Loose Coupler

shown, and we will now take up an easy method of making one.

The basis is to make two coils of wire that will slip one inside of the other, the outer one to have

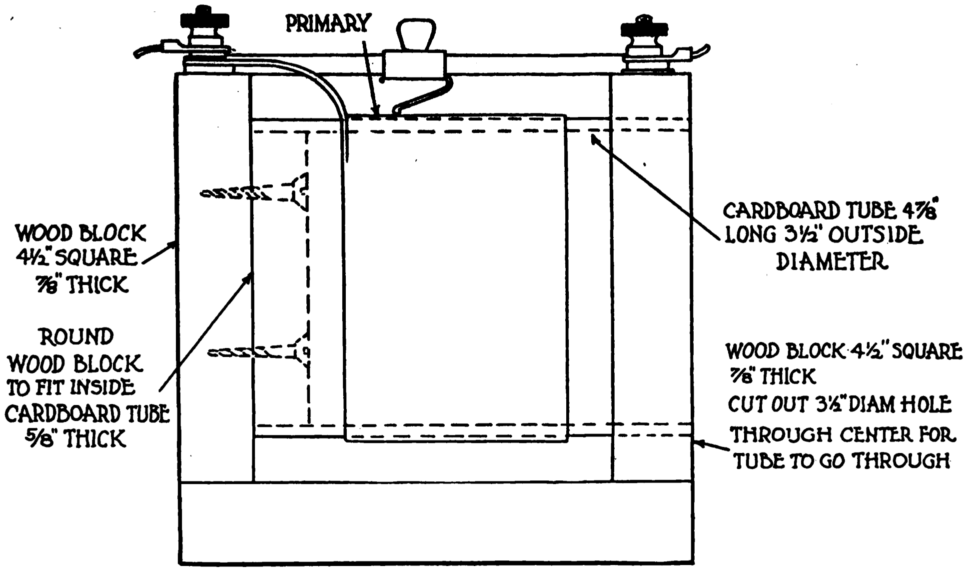

Fig. 56—Loose Coupler Primary; Side View

a slider on it so that the number of turns in use can be varied, while the inner one has taps, or connections from different parts of itself brought out to one end, so that the turns in it that are being used can also be varied. This gives quite a range of adjustment, and makes it easier to get rid of interfering sounds that make it hard to hear the message we want.

The appearance of such a loose coupler is shown in Fig. 55, the sketch being a cross-sectional one, as if the apparatus had been sawed in two. It consists of the outer part, or primary, and the inner part, or secondary. To get a clearer view of these reference should now be made to Fig. 56 which shows the primary by itself, and to Fig. 60 which shows the secondary by itself. Now if we should pick up the secondary of Fig. 60 and slide it from right to left into the primary of Fig. 56, we should have the complete outfit shown in Fig. 55.

Material Required to Build the Loose Coupler

Some 7/8″-thick wood.
Some 5/8″-thick wood.
Some 1/2″-thick wood.
Other sizes can be used if necessary, with slight changes in the dimensions.
1 cardboard tube 3 1/2″ outside diameter, 4 7/8″ long (primary).

1 cardboard tube 3″ outside diameter, $4\frac{5}{16}$″ long (secondary).
1 $\frac{3}{16}$″ or ¼″ square brass rod 5½″ long.
1 slider to fit the square brass rod.
2 binding posts. (About five or six binding posts will be required in all for the whole loose coupler outfit.)
10 round-head brass wood screws, about 1½″ long, for regulator.
¼ lb. No. 24 wire. This is enough for both windings. Insulation can be either single cotton covered, or double cotton covered, or enamel covered.
1 No. 10-32 by 2″ round-head brass machine screw, with three nuts to fit, or if this cannot be had, use a $\frac{3}{16}$″ stove bolt 2″ long, with suitable nuts. (This is the center bolt of the regulator.)
2 washers to fit the regulator bolt.
2 pieces $\frac{1}{32}$″ by ½″ by 2″ sheet brass. (One piece is for the regulator contact spring, and the other is for the connection that is seen in Fig. 57 connecting the square rod to the binding post.)
1 piece $\frac{1}{16}$″ by ½″ by 3″ brass strip for regulator handle.
12 ½″ flat-head brass wood screws to hold the cardboard tube to the end blocks.
Assorted screws or nails for holding the base strips to the end brackets. Screws should be used if possible.

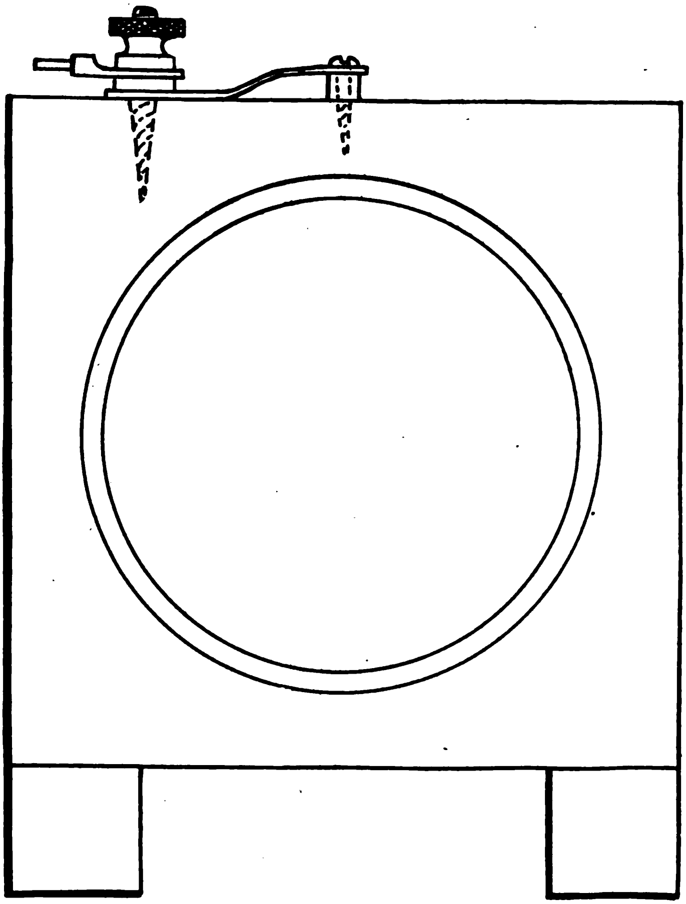

Fig. 57—Loose Coupler Primary; Right End

2 round-head brass wood screws ¾″ long to attach the square brass rod to the end blocks.

Two or three feet of No. 14 auto primary ignition wire for connecting the two regulator clips to binding posts which will be shown on an assembly drawing to be given later.

About 10 or 15 cents worth of water glass (obtainable at the drug store). This is used as a glue for sticking the wire to the cardboard tubes.

Making the Primary

First make the wood pieces shown in Fig. 56, the ends being the same size. The one at the right has the large hole cut through it for the cardboard tube to go through, while the one at the left is made plain. The hole in the right end piece can be marked out by placing the tube in the center of the block and drawing a pencil line around it, to mark the size of circle needed. Holes can then be drilled with a brace and small bit, and the edges can be trimmed with a sharp knife. A key-hole saw can also be used to advantage, or if a wood lathe is available a perfect hole of exactly the right size can be made. The tube should preferably be a tight fit in the hole.

A round piece of wood should now be cut out to fit *inside* of the tube, and, when of the right size, should be screwed in the exact center of the left-hand bracket or end piece. The two strips of

wood that form the base of the primary framework also act as a track for the secondary, the base of which slides in between these strips.

With the wood parts finished, we are ready to start on the tube. This should be given a coat of the water glass, but only over that part where the winding will come. The water glass can be used all over, but as it dries rather hard, it may make the tube fit too tightly at one end or the other, if the fit had previously been made just right. After this first coat of water glass has dried, the winding can be put on. The top view of the primary illustrated in Fig. 59 shows a good way of starting the winding. Two holes are bored in the cardboard tube, just big enough for the wire, and it is run down through one of these and up through the other, and then around the tube, until a space of 2½" has been covered. Two other holes can then be used to fasten the wire, to keep it from unwinding. In Fig. 59 it will be seen that the left end only of this winding connects to a binding post, while the right end is not connected, the other connection from the winding being made by the slider which works on the square brass rod.

After the tube has been wound it is ready to be again treated with the water glass, and this time the coating can be made all over. While still wet the tube should be assembled with the two end brackets. The water glass acts as a powerful cement, and if the tube is a good fit at both ends

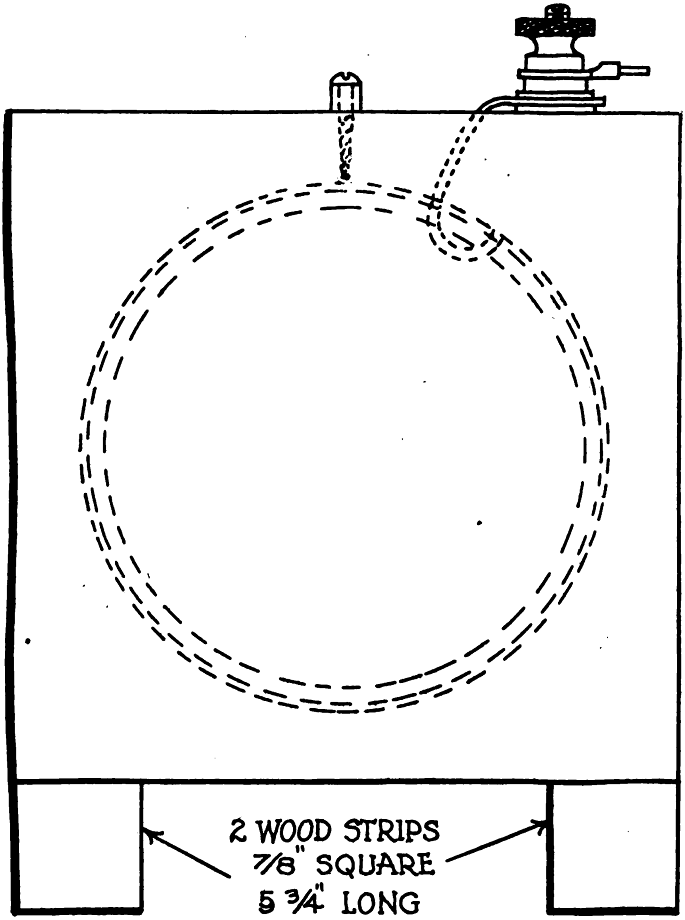

Fig. 58—Loose Coupler Primary; Left End

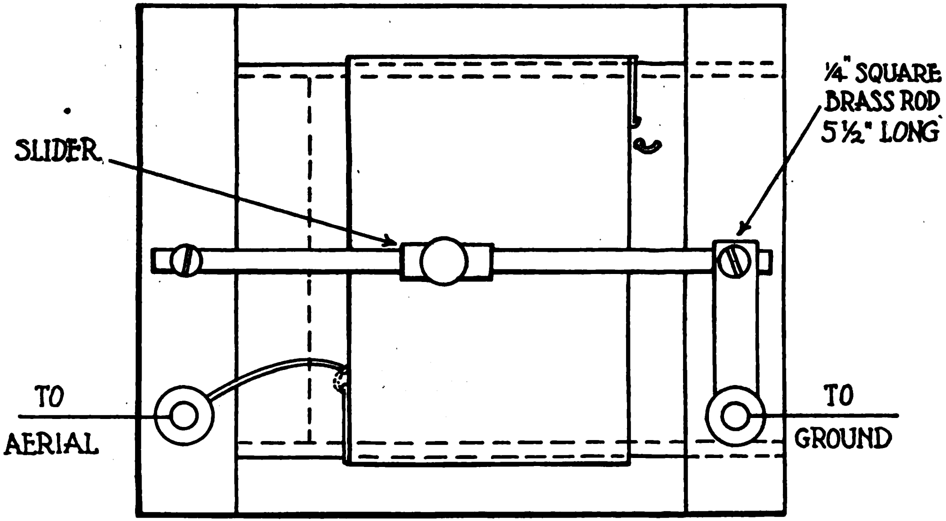

Fig. 59—Loose Coupler Primary; Top View

no other method of holding need be used, for the strips at the bottom and the brass rod at the top will also hold the framework together. The two strips at the bottom can now be fastened on, and when this has been done, we are ready to file away a portion of the winding insulation where the slider will come, as it must be able to make contact anywhere along the coil.

After the track of bare wire has been made on top of the coil, we are ready to put on the brass rod with its slider, the brass rod being connected to one of the binding posts by one of the thin brass strips, as shown at the right in Fig. 59. Fig. 57, which shows the right end of the primary, also shows this strap connection. The left end of the rod has the screw only which holds it to the end bracket. The left end of the primary is shown in Fig. 58.

Making the Secondary

As in constructing the primary, it is best to start by making the wood parts, these being shown in Fig. 60, which gives a side view of the whole assembly. The base and end bracket are quite easy to make, while the end piece for the tube is circular and cut out to fit inside. This should not be cemented to the tube as it may be necessary at some time to take the secondary apart to inspect the connections.

The next job is to make the regulator, which is merely a handle that turns to make different connections. For this purpose reference should be made to Fig. 55, Fig. 60, and Fig. 61, as each of these sketches show this detail. It might now be well to glue with the water glass the round piece of Fig. 60 to the end bracket shown in the same sketch. The location of this round block on the rectangular one is shown in Fig. 61. It is put in the center *one way* but *not the other way,* being 2¼″ down from the top, as shown by the dimension. With a compass a circle can now be laid out for the ten screws that are to be used for the contacts, and these should be well within the inside of the cardboard tube, but not in so close that the heads will be in danger of touching. As shown in Fig. 61, they are 1″ from the center.

Drill Holes for the Screws

If these ten screws are now put in without drilling the wood first, the end bracket will probably be split, so that it is well to try a hole in a spare piece of wood, to see that the screw will go in without much trouble and yet is not in danger of getting loose. The ten screws can now be put in place, and a hole put in the middle for the bolt that acts as a pivot for the handle. The construction of the handle is shown in Fig. 55 and Fig. 66, one end being curled up to act as a terminal into which one of the No. 14 primary auto ignition

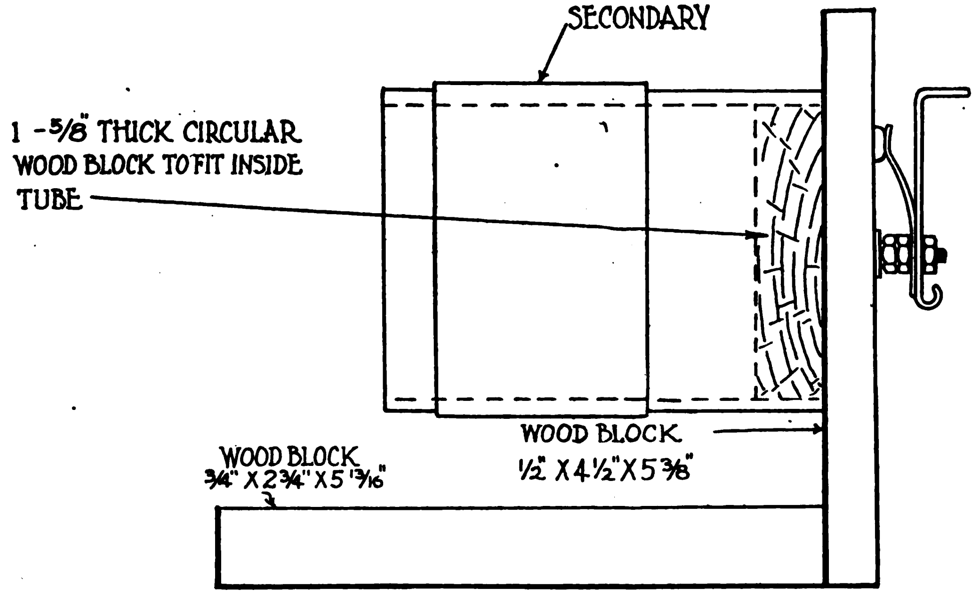

Fig. 60—Loose Coupler Secondary; Side View

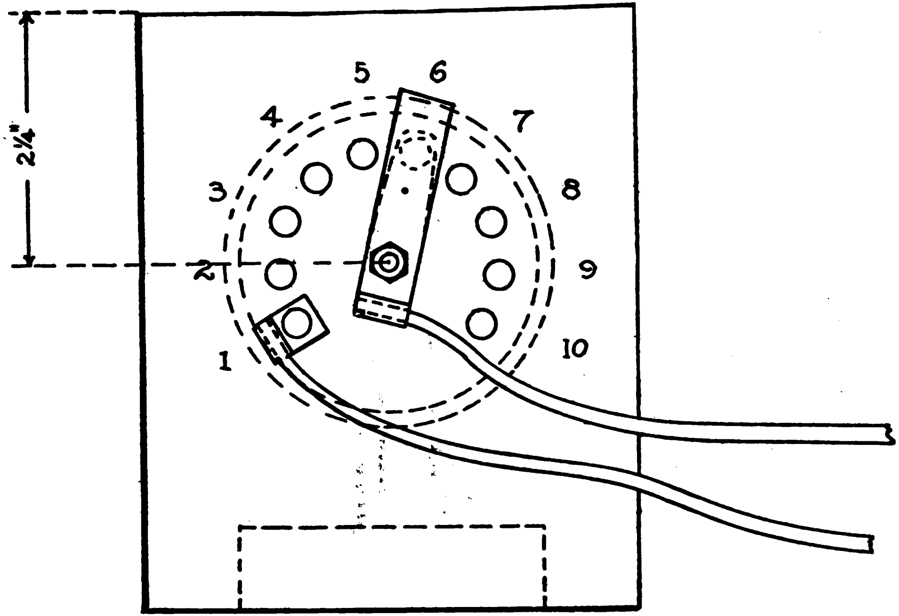

Fig. 61—Loose Coupler Secondary; End View Showing Regulator Making Contact With Various Taps

wires will later be soldered. The thinner piece of brass can be bent, as shown, and at any time if the contact is not good enough, the handle can be taken off and the spring bent so as to make better contact.

A thin terminal should be put under the head of the No. 1 screw, as shown in Fig. 61, and when all screws are in place the heads should be filed flat to make contact surfaces for the regulator contact spring.

Removing the Regulator Handle

In case it is desirable to take the regulator handle off at any time, it may be found that the whole screw will try to turn so that it is difficult to get the nut off. Under these circumstances the secondary should be entirely removed from the primary, so that a screwdriver can be used to hold the screw from turning. The spring and handle of the regulator should be fastened together with a rivet, as shown in Fig. 55, and the whole assembly should be held tightly together by the nuts as shown. The turning action will then take place in the wood, the hole drilled being such that the bolt turns with just a little friction. If too tight at first, the bolt can be worked in and out until the hole is enlarged just enough to give easy action.

Winding the Secondary

This work must be done a little more carefully than when winding the primary, as it is necessary to make a number of connections to the regulator screws that stick through the back of the end bracket. Referring to Fig. 62, we see the tube, which must have a coat of water glass where the winding will be. We also see the end bracket turned so that the back of the regulator is up and the points of the ten screws are showing. The numbers shown here correspond to those shown in Fig. 61.

In the tube a number of holes are shown, but these should be put in only as needed or they may be found to be in the wrong place. Starting with the hole at the left, which is just about 5/8″ from the end, we run the end of the wire through to the inside of the tube and over to the No. 1 screw. It will be inconvenient actually to attach this wire to the screw and still be able to put the winding on, so that this wire should merely be left sticking out two or three inches, so that connection can be made later.

Ten turns of wire should now be wrapped around the tube, and at the tenth turn another hole should be put in the tube, and the wire cut off so that it is long enough to go down into the tube and over to the right, where it will later be fastened to the No. 2 screw. From the No. 2 screw the wire now goes back and up from the inside of

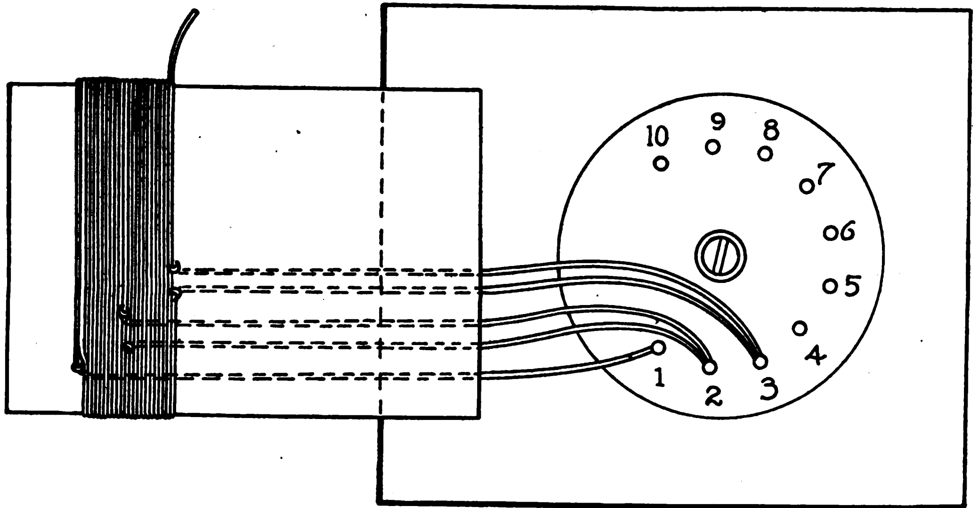

Fig. 62—Loose Coupler Secondary; Showing Method of Winding Tube and Connecting to Screws on Back of Regulator

the tube to the outside, so as to continue the winding, which will appear to be nearly continuous when finished, although at every ten turns there will be a connection to one of the regulator contacts.

The No. 24 wire specified will go on with about 42 turns to the inch; about 2″ of this winding should be applied, which would give about 84 turns. This can be increased to 90 turns, which will just use up the ten screws. After the winding is completed the wires should be wrapped *around the right screws* and *soldered to them,* after which the regulator end bracket and tube are ready to be assembled. Water glass can be used as before to coat the winding, but in assembling it might be better to use small screws through the cardboard tube into the wood blocks, so that if a wire breaks off, the secondary can be taken apart and the wire repaired.

Importance of Soldered Connections

Too much stress cannot be laid on the vital need for good connections, and the only way to be sure that a connection will remain good is to solder it. For this reason it is absolutely necessary to solder the wires to the screws that show up at the back of the regulator.

There are also a number of other places that really should be soldered, to make sure that the possibility of future trouble has been reduced to

a minimum. Going back to the primary, we see in Fig. 59 *three* places where solder should be used. At the connection of the winding to the "aerial" binding post, while it may be clamped tightly, a drop of solder will insure a good connection. In the same way solder should be used to connect the thin brass strip at the right to both the brass rod and the "ground" binding post. Then in this circuit the only rubbing contacts that we shall have will be the slider on the winding and on the brass rod.

We have already mentioned the soldered connections required in the secondary, except that in Fig. 61 the wires that go to the handle and the No. 1 screw should of course also be soldered in. These leads can be left about 15″ long, and will connect to binding posts that will show up in a following Message.

MESSAGE NO. 14

HOW TO MAKE THE CONDENSERS FOR THE LOOSE COUPLER SET

In the last message we described how the loose coupler itself could be constructed, this being used as shown in the diagram in Fig. 53. In this same diagram we also used, however, a variable condenser connected right across the secondary and also a fixed condenser connected across the phones, and we will now take up simple ways of making both of these.

Making the Variable Condenser

While variable condensers can be purchased, it is often the desire of the mechanically inclined person to make as much of the equipment as possible. The type of variable condenser usually seen is made of two sets of sheet-metal pieces, one set sliding or rotating in between the plates of the other set. With this construction it is quite likely that a slight inaccuracy would make a plate from one set touch a plate from the other, which would short the condenser and prevent the operation of the set.

In Fig. 63 is shown an ordinary envelope, with the two ends cut so that pieces of sheet metal, as shown at the right, can slide through the envelope from one end to the other. Between these two

pieces of metal, which are placed with the handle end at opposite ends of the envelope, is placed a piece of mica or waxed paper, which acts as the insulator between the two metal pieces and keeps them from touching each other. Such a condenser will have its greatest capacity when the two pieces of metal are entirely inside of the envelope, so that they lie on top of one another and would touch except for the mica or wax paper between them. The capacity will be practically zero when each plate is pulled half-way out, so that they do not overlap each other. A wire soldered to each metal plate completes the variable condenser.

Making the Phone Condenser

In Fig. 64 is shown a method of making the simple condenser which is connected across the phones. This is made of a piece of wax paper or paraffine paper, which can be obtained from some loaves of baker's bread, or is often found used as a wrapper around chocolate bars. An ordinary flat iron, not too hot, can be used to iron the wrinkles out of such paper, so that a good condenser can be made. With the paper cut to size, it is next folded in a sort of S or Z shape, as shown, and then strips of tinfoil are inserted in the spaces of the S, as indicated. With this construction we again have two sheets of metal laid one on top of the other, but again they do not touch owing to the way the paper is used between

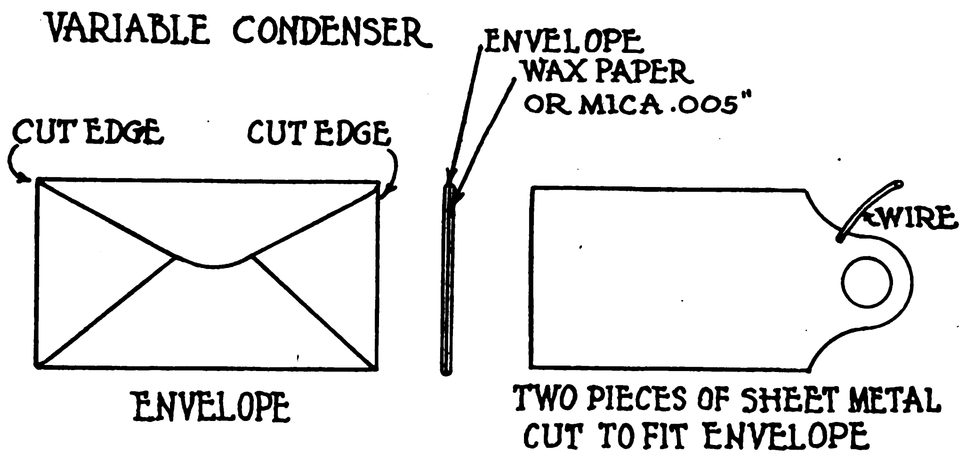

Fig. 63—Simple Construction for the Variable Condenser

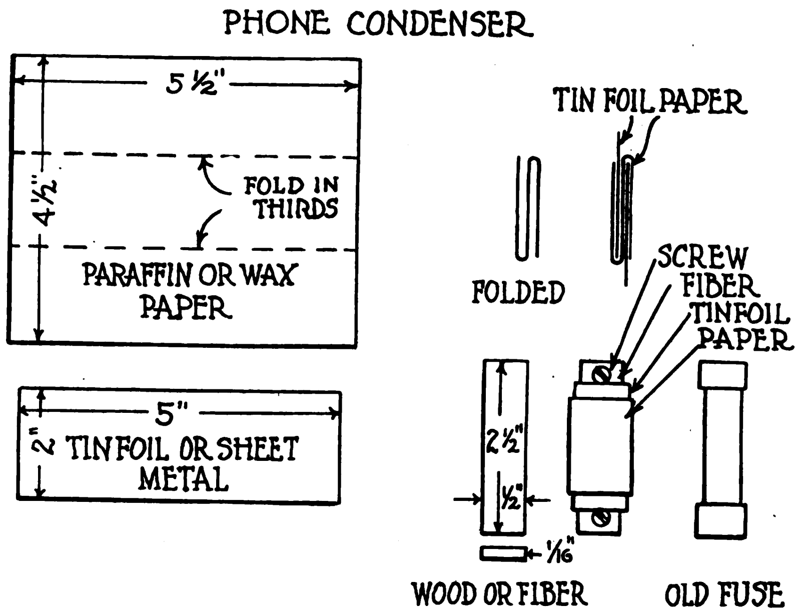

Fig. 64—Simple Construction for the Phone Condenser

them. This will make a long flat condenser which can now be made neater and more compact by rolling around a piece of wood or fiber, as indicated in the lower right-hand portion of the figure. Finally two machine screws can be used with their heads coming down on top of the tin foil, so as to make contact with it, while nuts on the other side will hold the condenser assembled and also act as binding posts.

If an old fuse and a pair of fuse clips happen to be available, the condenser might be attached to it, with one strip of tinfoil soldered to one end of the fuse and the other strip soldered to the other end. This must be a blown fuse, not a good one, the main difficulty in this method being the soldering of the tinfoil to the end caps without melting the foil.

If it is desirable to purchase the parts for a loose coupler receiving set, the following list may prove of assistance.

Loose coupler.*

Crystal detector.

Pair of receivers or phones; should be wound from 2,000 to 3,000 ohms; 2,200 or 2,400 ohm receivers work very well.

*While the loose coupler set is more satisfactory than the one using a two-slide tuner, it is desirable that the advantages of the audion bulb set also be considered. This type is capable of receiving over distances of 1,000 miles or more, while the crystal set is limited to a radius of some 25 or 50 miles. The audion set is described in Message No. 18.

About 100 ft. of stranded aerial wire; the exact amount will depend on the room available for suspending the aerial. (See Message No. 17.)

Two or more insulators for the aerial, depending on the way it is supported.

Phone condenser.

Variable condenser.

Three binding posts, for assembling the apparatus, as shown in Fig. 65.

A few pieces of wire for making connections.

Connect as shown in Fig. 53, which shows the circuit diagram, or refer to Fig. 65 which shows the apparatus, with the connections to aerial, ground, and phones indicated. The ground connection is made to water pipe or radiator.

MESSAGE NO. 15

ASSEMBLING AND USING THE LOOSE COUPLER SET

The set just described should receive over a distance of at least 25 miles, but the successful use of the finished outfit will depend somewhat on the way it is laid out for ease of adjustment and operation. In Fig. 65 we show a layout in which the various units are accessible and easily adjusted with either hand. Also with slight changes in adjustment, the left hand can be used while messages are being recorded with the right hand. For a left-handed person, the arrangement might be just reversed.

As shown in Fig. 65, the loose coupler is mounted at the upper left-hand corner of the instrument board, the space below being left clear so that the secondary can be pulled as far out as necessary when tuning. The crystal detector is located at the back of the board at the right, while the variable condenser is toward the front of the board where it can be easily adjusted.

The fixed condenser of Fig. 64 is shown connected between the two binding posts that are used for the phone connections. In laying out this part of the board it might be possible to mount this condenser under the board by cutting away the wood on the underneath side. The two screws that were used in making the condenser

terminals would then extend up through and would also serve as the binding posts for the phones.

Tuning the Loose Coupler Receiving Set

The instructions for testing the crystal detector as given on page 109 of Message No. 9 should also be followed in testing the crystal for the loose coupler set. We are then ready for tuning.

To start with, the coupling should be close, that is the secondary should be pushed all the way in, and the regulator handle on the secondary should be turned to the right, so as to have the use of all the turns of the secondary. The variable condenser capacity should be made as small as possible by pulling each plate about half-way out, so that they do not overlap. The slider on the primary should now be pulled toward the front of the board. *We have started then to tune by putting all possible inductance in the circuit and by reducing the condenser capacity to the minimum.*

The next step is to put on the phones and to adjust the variable condenser slowly in and out. Then move the slider up about ½″ and again work the condenser plates in and out slowly. Continue in this manner until a point is reached where signals are heard. If no results are obtained, move the regulator handle on the secondary to the left one notch, and repeat the process de-

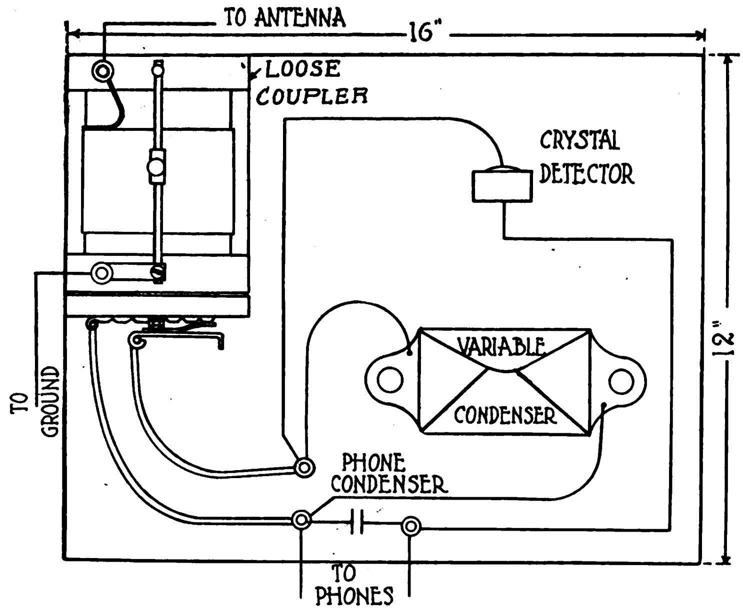

Fig. 65—Loose Coupler Receiving Set Assembled

scribed, using each notch on the secondary and every half-inch on the slider.

When signals are heard, move the slider to the point where they are heard best and clearest; then try the different secondary taps where the signals are heard, varying the condenser on each position of the regulator. When the best secondary tap and condenser position is obtained, then readjust the primary slider to see if any improvement is to be had.

After the tuning is as good as possible with close coupling, start to pull the secondary out. Points will now be found where the signals disappear, and other points may be found where the signals appear, and are much stronger than with the secondary all the way in. The point where signals are strongest is of course the one to use. After tuning a few times, the operator will know about how the set should be operated so as to get best results, and all of the tuning process just described will not be necessary.

Tuning Out Interference

Close coupling is called "stand by," and usually will catch most everything that is in the air. It is not so good, however, when a certain message is wanted, owing to interference from other messages. For this reason the loose coupling is used as it tunes out one message and picks up another;

the exact point to use, however, to get the message you want being naturally a matter of experiment.

Trouble-Shooting Suggestions

It sometimes happens that difficulty is experienced in getting good results, which may be due to trouble in the equipment. As a few simple tests will show up ordinary troubles, they will now be given.

Checking the Crystal Detector

The buzzer method was given in Message No. 9. Another way is to wet the finger and touch it to the aerial terminal of the loose coupler. A click in the phones indicates that the detector is in working order. Another way is to disconnect the aerial lead and make and break the circuit to its terminal on the loose coupler. This also will give a click in the phones with a good detector.

Testing the Condensers

To test these a lamp circuit should be made and connected to one of the regular house wiring sockets, as shown in Fig. 66. From the construction of the condenser we know that while there are two pieces of metal in each condenser, owing to the insulation they are not supposed to touch each other. In the test illustrated in Fig. 66 the condenser will then be in proper order if the lamp

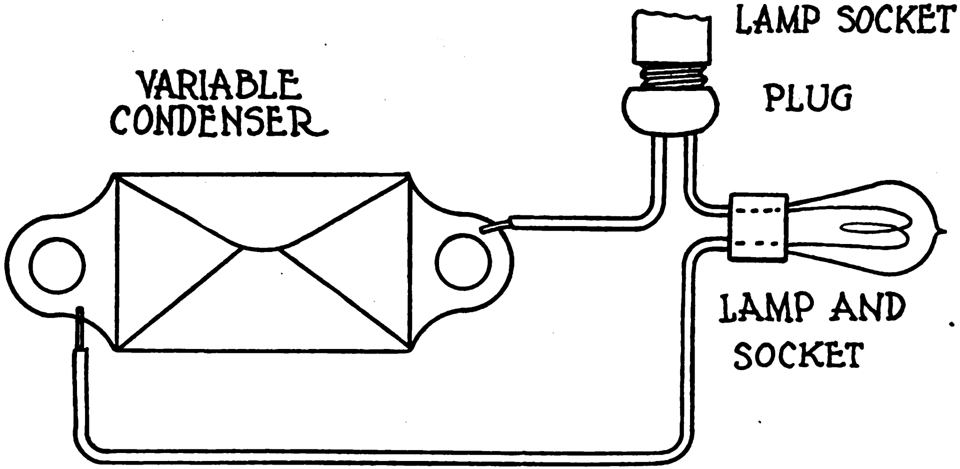

Fig. 66—Method of Testing Condenser

does *not* light up, but if the lamp does light, it shows the condenser is shorted, that is, the two metal plates are touching.

In similar manner the phone condenser can be tested, and in making tests on either condenser all other connections should be removed. The two windings of the loose coupler can also be tested with the 110-volt lamp by removing the various connections. To test the primary the wires from our test-lamp circuit would go to the antenna and ground binding posts, and this time the lamp *should* light up, for it is a circuit now that we want. The slider should now be moved to various positions to see that good contact is made all the way along.

In similar manner the secondary can be tested to see that good contact is made at each of the taps, and that there are no breaks in the winding.

With everything apparently correct, but with still some difficulty encountered in receiving signals and messages, it would be well to borrow a crystal from a friend whose set is known to be working well, to see if a more sensitive crystal will give the required results.

MESSAGE NO. 16

THE CARBORUNDUM DETECTOR

The usual crystal detector uses a crystal of galena, which, while it is the most sensitive crystal that we can find, has one disadvantage, in that it is easily jarred out of adjustment. For this reason in a set where the crystal detector is likely to be disturbed so that the adjustment is likely to be lost, a more reliable type is desirable.

This type, while not usually employed on sets made for receiving broadcast signals, is used on boats on the lakes, where it is essential that reliability be secured at all costs, and where the roll of the boat might throw out of adjustment a more sensitive device. For this reason the carborundum detector is used for certain purposes, although giving weaker signals, but also giving operation that is more dependable.

The Potentiometer

Here we are going to ask you to look carefully at the explanation of an electrical principle which is the foundation of the action of the carborundum detector, for if you do not understand this principle, you will not know why this type of detector works or why it needs a battery.

The potentiometer is a device for getting any desired voltage from a fixed voltage. It is usually

made of a carbon disk around which a contact arm moves to make a connection with any point on the disk.

In Fig. 67 we have a battery, a coil of wire which is marked "High Resistance," and also a voltmeter. We know of course that as the high resistance is connected from one terminal of the battery to the other, a current will flow, going from the plus terminal to the end marked (*A*), then down through the coil past (*B*), (*C*), (*D*), (*E*), (*F*), and (*G*), and then back to the negative terminal. Now we know that a battery has a certain electrical pressure or voltage which is always trying to send out current. Or another way to look at it is that the battery is lifting electricity up hill, and whenever it finds a chance it seizes the opportunity to run down hill again. In the coil from (*A*) to (*G*) it has this chance, and runs down hill to the negative terminal only to be lifted up to the positive terminal again, and this cycle or circuit keeps being repeated as long as the coil is connected.

Now it will be quite apparent that if you climb a hill and come down again to the starting point, the distance you went up is the same as the distance down. In similar manner the distance up, electrically, being 6 volts, the distance down, or loss of voltage in the resistance, is also 6 volts. Here a difference is found, however, for if we try to measure the electrical rise of voltage as it is

produced in the battery, we can measure only one or two or three cells, so that we can get a reading of either 2 or 4 or 6 volts. This is because we cannot get our voltmeter leads into the battery anywhere to get intermediate readings.

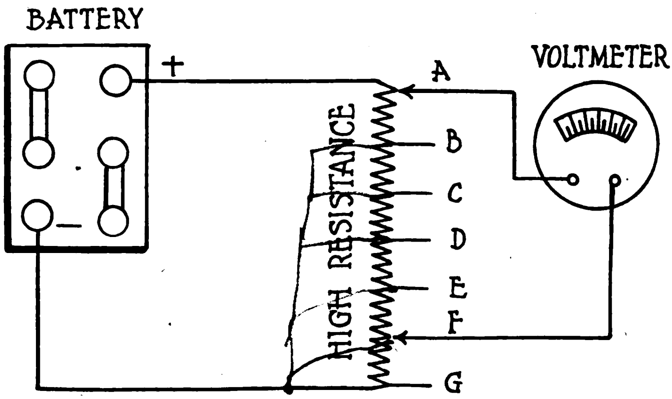

Fig. 67—The Potentiometer: a Method of Getting Any Desired Voltage From a Fixed Voltage

On the resistance coil, however, it is quite different, for we can slide the wires from the voltmeter almost anywhere along the wire, and the reading will depend on the distance of the leads apart along the wire. For example, if the meter leads are at the ends of the coil, the reading will be the battery voltage, or 6. However, if we start to slide one of the leads along toward the other the reading starts to become less, and, as shown in Fig. 67, would be 5 volts, for the meter is con-

nected across but five-sixths of the whole voltage. At (*E*) we should have 4 volts, at (*D*) 3 volts, etc. It would also be possible to move both leads, and if we assume that one wire is connected to (*C*) and another to (*D*), we would have a reading of but 1 volt.

In this illustration the voltmeter is being used as an indicator of electrical pressure, much as in a water system a pressure gauge might be connected in to read the water pressure. In a tank, for example, the pressure at the bottom depends directly on the depth of the water, and in similar manner the reading of the voltmeter will depend on the electrical height. The reading from (*A*) to (*G*), therefore, gives us the greatest available electrical height or voltage, which is the same as that of the battery, while a reading across less resistance, such as from (*A*) to (*F*), will give a reading that is reduced in proportion to the reduction in the resistance, across which the reading is taken.

In Fig. 68 we have the same sort of a device, but instead of the voltmeter we have a carborundum detector connected so as to receive varying voltages, depending on the location of the sliding contact. The carborundum detector is made similar to the galena detector except that a blunt point should be used and the pressure can be greater. The galena crystal, as you remember, requires a sharp point and light contact.

When we speak of a "crystal" in radio receiving, the word does not refer to a piece of glass in the shape of a prism. We refer instead to certain minerals, as originally mined, which are in crystalline form.

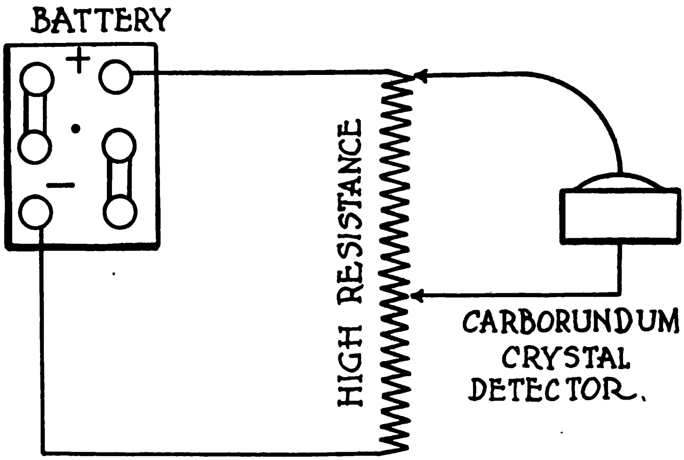

Fig. 68—Use of Potentiometer to Get Desired Voltage Across Carborundum Crystal

Change of Current with Voltage

We now have to consider another electrical principle in connection with this detector, and that is the change of current (electrical flow) with change in voltage (electrical push, or pressure). We might illustrate this condition in a general way by considering the action of an automobile

when the driver steps on the gas lever. The engine exerts more force (mechanical voltage) and the car goes faster (mechanical current).

In the same way increase of electrical voltage will send more current through a circuit. In Fig.

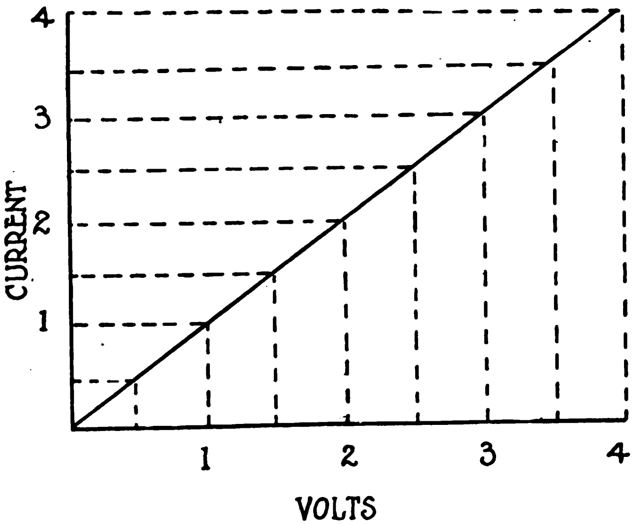

Fig. 69—Change of Current in a Copper Wire With Change in Voltage

69 we have a "curve" which in this case is a diagonal straight line which represents the change in current with change in voltage, when we are considering the action in a copper wire. For example, with a 1-volt pressure we have one unit of current. With 2 volts we have two units of

current, and so on, as far as we wish to go, as long as the wire does not get hot, which alters the condition slightly. Roughly, however, we say that the current continues to be proportional to the voltage.

Change of Current with Voltage in a Carborundum Detector

In Fig. 70 we will now study the action that takes place when the voltage across a carborundum detector is changed. Starting at the lower left-hand corner we see that for slight increases in voltage the current increases steadily. At a certain point, however, which we call (X) an increase in the voltage begins to make a more pronounced rise in the current, and continued increase in voltage again creates an additional current flow. Another way to look at it is that the resistance to flow across the contact of the blunt point with the crystal has been suddenly reduced, and it is this peculiar property of the carborundum detector which enables us to use it in radio receiving.

We will now assume that we have an oscillating voltage rapidly alternating, and rising first to ½ volt in one direction and then to ½ volt in the other or negative direction. We will now also assume that we have adjusted the potentiometer in Fig. 68 so that we have just 2½ volts across

the crystal, which on the curve in Fig. 70 would mean that the condition was represented by the point just below the point (X). Now if at the same time that we have 2½ volts across the crystal and the current of ½ unit going through it we apply the oscillating or alternating voltage, we

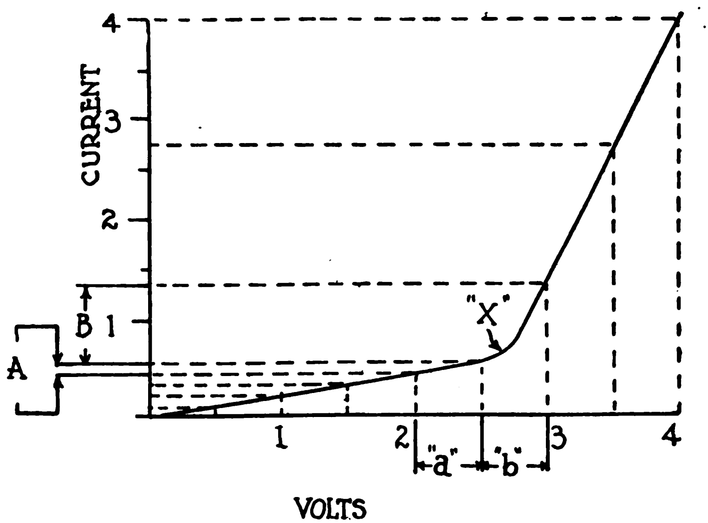

Fig. 70—Change of Current in a Carborundum Detector With Change in Voltage

should first have the sum and then the difference of these two voltages acting to send current.

The 2½ volts from the battery with the ½ volt from the alternating current helping, would be the same as 3 volts, while with the oscillating voltage in the reverse direction we should have the

difference, or 2 volts, acting on the crystal. This gives a rise of (*b*) in volts (see Fig. 70) which produces a rise of (*B*) in the current. On the other hand, a drop of (*a*) volts (Fig. 70), which is the same as (*b*), gives a very small drop (*A*) in the current, compared to the rise at (*B*).

Receiving Circuits for Carborundum Detector

In Fig. 71 we have the details of the way in which the principles just explained are to be practically used so as to receive radio messages on the phones.

As in the case of the galena detector set, we have a primary tuning coil in the aerial circuit and also a secondary with the regulator, this being the same as the set described in Fig. 65 and previous illustrations. The oscillating currents in the primary will produce oscillating voltages in the secondary, which will send current through the detector and the phones. If it were not for the dry cells and the potentiometer, however, the current would go through the detector as well one way as the other, and there would be no sound received.

Now, by adjusting the slider on the potentiometer, we can maintain a voltage equivalent to the point (*X*) in Fig. 70, so that there will be a comparatively heavy current through the detector and phones in one direction, and hardly any in

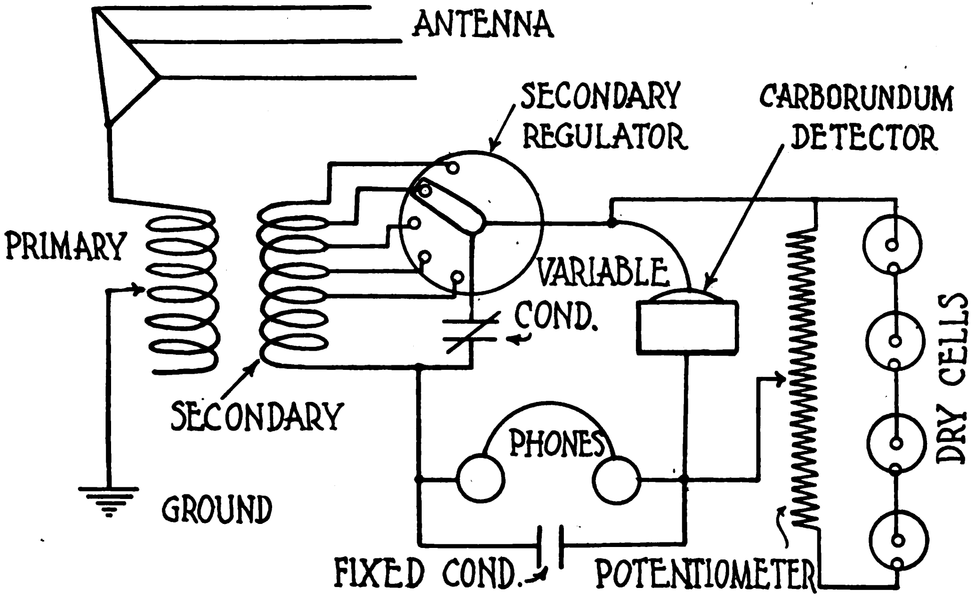

Fig. 71—Receiving Circuits for Carborundum Detector Set

the other direction, which means that while we do not blot out all of the current in the wrong direction, we do weaken it so that the current in the other direction predominates and makes the receiving of the messages possible.

How to Make the Potentiometer

The general method of making the potentiometer is similar to that of making the double-slide tuner described in Message No. 9, except that the diameter can be much smaller if desired. It is very important to use small wire, however, the smaller the better, so that very little current will be taken from the dry cells.

Another method of producing a high-resistance potentiometer is to use a lead pencil split so as to leave the length of lead projecting above the wood. The two ends can then be connected to the dry cells and the slider arranged to operate over the length of the lead.

How to Tune the Carborundum Set

Tuning the carborundum set is similar to tuning the galena set, as described in Message No. 15, where the loose coupler was also employed. Before starting, however, the potentiometer should be set in about the middle position, which will give about 2 volts to the crystal. As soon as signals are heard, the slider on the potentiometer

should be adjusted to the point where they are most distinctly heard. Then the process of tuning can be continued, as in the case of the other type.

MESSAGE NO. 17

AERIALS

The design of the aerial will determine the wave length that can be obtained without tuning coils or condensers of any kind. In practice, however, there are two difficulties in the way of making the aerial just right. One is that the length required is such that it is necessary to live where a large open space is available. The other is that even if the aerial by itself should be correct for one wave length, we could not listen to any other wave length.

The wave length naturally received by the aerial is about four times its length, so that for receiving a 360-meter wave we would need an aerial about 90 meters long. Now a meter is somewhat over three feet, so that our aerial would have to be somewhat more than 270 feet long, and many of us do not have the necessary space available for such a length, either in the house or yet outside of it.

For practical purposes, therefore, we make the aerial as long as we can, say 50 to 100 ft., and then use the inductance or flywheel effect of the tuning coil to slow it down to be right for the wave length we wish to receive.

Aerial Inductance and Capacity

As the radio waves cut the aerial they produce oscillating currents which form magnetic circles or lines of force around each wire, so that the length of the wire increases this inductive effect. Between the aerial and ground we also have air, which is an insulator, and as the aerial and ground are both conductors, we have a condenser. (See Message No. 10.) Now if, instead of one wire we should use two wires side by side, we should have a greater capacity to the condenser action of the aerial, because the area of the upper conductor in our condenser has been increased. At the same time, however, we have reduced the magnetic or inductive characteristics of the aerial because the lines of force around one wire neutralize in a measure the lines around the other.

Now the wave length will depend not only on the capacity but also on the inductance (as we saw in Message No. 6), and as we have increased one and reduced the other, we have not made an appreciable change in the wave length we can receive by adding another parallel wire to the aerial. This is similar to our spring board illustration, assuming we might make it more springy and then reduce the weight on the end of the board. One change would about offset the other, so that the action would be about the same as before the change was made. The use of more

than one wire, however, does reduce the resistance of the aerial, resulting in its giving better signals.

Location of Aerial

With the best of conditions the aerial can be run from one end of the house to the other, inside as well as on the roof, although the outside aerial is recommended when possible. The greater height at which it can be suspended also has some effect on the ability that it has to catch signals. We must remember, however, that the walls, wood, bricks, and plaster that make up our house are as nothing to the radio waves and offer no obstruction whatever. The only difference in getting the aerial inside of the house is that it may be too close to water pipes, radiators, etc., any of which may interfere somewhat with its action and reduces the distance at which messages can be received.

Connections to the Aerial

Lead-in wires coming to the tuning coil may be connected to the end of the aerial or to the center. If connected at the end, it is known as an inverted "L" aerial, while if connected to the center of the aerial, it is known as a "T" aerial.

The umbrella aerial is used for field work where a portable outfit is to be set up. It consists of a pole to which a number of wires are attached at

the top. These come down to insulators spaced in a circle around the pole, and from the insulators wires go to stakes in the ground. In this manner the aerial leads also act as the guy wires to hold up the pole. Owing to the fact that the ends of the different wires come quite close to the ground, the capacity of this type is increased, so that it naturally receives a longer wave length and does not need so much inductance in the tuning coil.

In the case of an aerial constructed on the roof or outside of the house, it is advisable to insulate carefully the lead-in wire by running a porcelain tube through the window casing or other part of the house. This is not absolutely necessary in dry weather, as dry wood itself is a very good insulator, but when it gets wet it might cause trouble as a result of electrical leakage through the moisture.

MESSAGE NO. 18

THE AUDION BULB RECEIVING SET

While usually costing somewhat more than the set which uses the crystal receiver, the audion bulb set is much more satisfactory, as the messages are more clear and distinct. In the crystal set it is the energy actually transmitted through the space between the sending and receiving sets which is used to operate the diaphragm of the phones. As the distance from the sending station is increased beyond 25 miles, or at the most 50 miles, it becomes nearly impossible to make the crystal set work satisfactorily owing to the waves becoming weaker at greater distances.

The audion bulb set works on a somewhat different principle, however, for while it uses the same radio waves, it uses them merely to operate the bulb, which is somewhat like an ordinary electric light bulb, although smaller. Other circuits through the bulb are controlled in such a way that the actual energy to work the diaphragm of the phones is received from batteries, from which we can get plenty of energy.

For this reason audion sets have been known to pick up signals sent across the whole United States. To hear for a distance of 1,000 miles is no problem at all with a good audion set. This method of receiving also makes possible the increase in the sound to the point where it can be

heard all over the room, thus eliminating the use of the individual receiver sets, the amplifier being the invention which makes this possible.

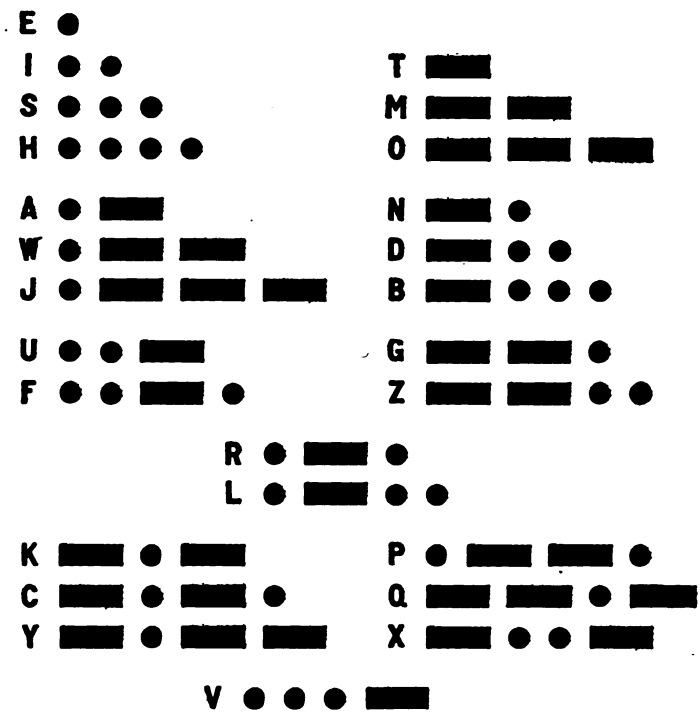

Fig. 72—The Continental Wireless Code

While the operation of such sets is quite simple, their construction and principle of operation is quite complicated, so that this phase of the subject

we can afford to pass up, especially in view of the fact that the large electrical companies making these sets put them out in such a form that all binding posts are plainly marked indicating the various connections that need to be made to aerial, ground on water pipe, etc.

With the understanding that you get from the study of this book together with the instruction the dealer gives when you secure an audion set, there should be no question about getting complete satisfaction and much enjoyment from this the most wonderful invention of the ages.

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